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A CAD-E APPROACH TO A BALL ROTOR SAFE AND ARMING DEVICE

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
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DOVER, NEW JERSEY

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M505A3 fuze, 20 mm projectile
M503A2 fuze, 57 mm projectile
CAD-E approach
Euler's equations (see reverse side)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer-aided design and engineering approach was developed to study ball rotor safe and arming devices. This approach used mathematical modeling procedures to design inert and loaded prototypes. Ballistic tests guided by a statistical plan were conducted to verify the mathematical models. The inert fuzes were monitored by a flash x-ray system to determine arming distances.

(see reverse side)

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19. Key Words (cont)

M533 Fuze, 40 mm projectile
Flash x-rays tests
Weight computer program
Spin-73 computer program
One-shot sensitivity test for extreme percentage points
Time-step simulation computer program

20. Abstract (cont)

A small quantity of 20, 40 and 57 mm projectiles was used. A comparison of the 57 mm results with those of an extensively analyzed and standard 57 mm fuze substantiated the viability of this approach.

ACKNOWLEDGEMENT

Portions of this report are excerpts from writings and comments by Dr. David Breed. Dr. Breed is the originator and analyst of the mathematical model on which this effort was based. Other Breed Corporation personnel gratefully acknowledged are: Allen Breed, advisor; Ted Thuen, design engineer, and Herman Stoekle, hardware and test technician.

TABLE OF CONTENTS

INTRODUCTION

This is a performance assessment of Contracts DAAA21-73-C-0650 and DAAA21-74-C-0481. The Breed Corporation was awarded these contracts to conduct studies on a computer-designed fluid-immersed ball rotor safe and arming (S&A) device. The concept was adapted from the simple, inexpensive S&A device found in the 20 mm M505A3 fuze.

The objective of the study was to demonstrate the viability of a computer aided design and engineering approach to the ball rotor S&A system. This required that:

1. an experimental S&A device be developed which could be used with different caliber projectiles

2. the safe arming distance relative to an existing ball rotor S&A system be extended

3. the arming range be controllable.

TIME STEP SIMULATION MATHEMATICAL MODEL

Description

The design of the Breed Corporation ball rotor device was guided by Dr. David Breed's "Time Step Simulation" computer program. This program was used to predict the alignment time of the ball rotor. The input parameters were:

Nutation eccentricity and angular velocity
Housing eccentricity magnitude and orientation
Clearance between ball and housing
Ball initial angular velocity
Shell initial angular velocity
Shell deceleration or drag
Ball mass
Ball inertia matrix about the geometric center
Shell velocity
Ball eccentricity matrix
Ball/housing coefficient of friction
Ball initial position
Angle at which ball is considered aligned
Fluid density and viscosity (if fluid is present)
Housing geometry as it affects contact point between ball and housing.

In addition, there is a series of subsidiary programs which can determine the inertia and eccentricity matrices for arbitrary ball geometries. For example, the effects of holes, slots, bands, grooves, or composite structure can be considered.

Three degree- and six degree-of-freedom models are available. The three degree-of-freedom program considers only rotation (rigid body) while the six degree-of-freedom program considers rotation as well as translation (deformation). These models are based on Euler's Equations which relate frictional forces to inertial forces (fig. 1).

Euler's Equations

$$I_1 W_x - W_y W_z (I_2 - I_3) = N_x \tag{1}$$

$$I_2 W_y - W_z W_x (I_3 - I_1) = N_y \tag{2}$$

$$I_3 W_z - W_x W_y (I_1 - I_2) = N_z \tag{3}$$

also, $$W_n \approx \frac{I_p}{I_t} W \tag{4}$$

$$N_e = M_e W^2 E_e \tag{5}$$

substituting equation (4) into (6),

$$N_n = M \frac{(I_p)}{(I_t)} 2W^2 E_n . \tag{7}$$

Normally,

$$\frac{N_e}{N_n} >> 1 \tag{8}$$

dividing equation (5) by (7),

$$\frac{N_e}{N_n} = \frac{M_e W^2 E_e{}^2, \; W \; E_n}{M_e \frac{(I_p)}{(I_t)}^2} \tag{9}$$

$$\frac{N_e}{N_n} = \frac{E_e}{\frac{(I_p)}{(I_t)} E_n} \tag{10}$$

I = Moment of inertia

N = Friction torque on rotor ball about X,Y, Z axis

N_e = Eccentricity friction torque

N_n = Nutation friction torque

W_n = Nutation frequency (spin)

W = Projectile frequency (spin)

M_e - Effective mass of rotor ball

E_n = Nutation eccentricity

E_e - Projectile eccentricity

I_p = Polar movement of inertia of projectile

I_t = Transverse movement of inertia of projectile

Ball Rotor Dynamics

Analyses indicate that the arming range of a ball rotor is determined by the rate which energy is supplied to the ball through the ball's contact with the cavity in which it is confined. The contact supplies external energy to the rotor, causing it to align and complete the explosive train. This external energy is proportional to the frictional forces between the rotor and the cavity. Reducing the frictional forces results in a longer non-arm distance since less friction causes less energy to be supplied to the rotor by contact with the rotor cavity.

Consequently, lack of friction could produce a non-aligned rotor and an infinite arming distance. Lack of friction could be the result of many factors:

1. eccentricity friction torque

2. nutation friction torque

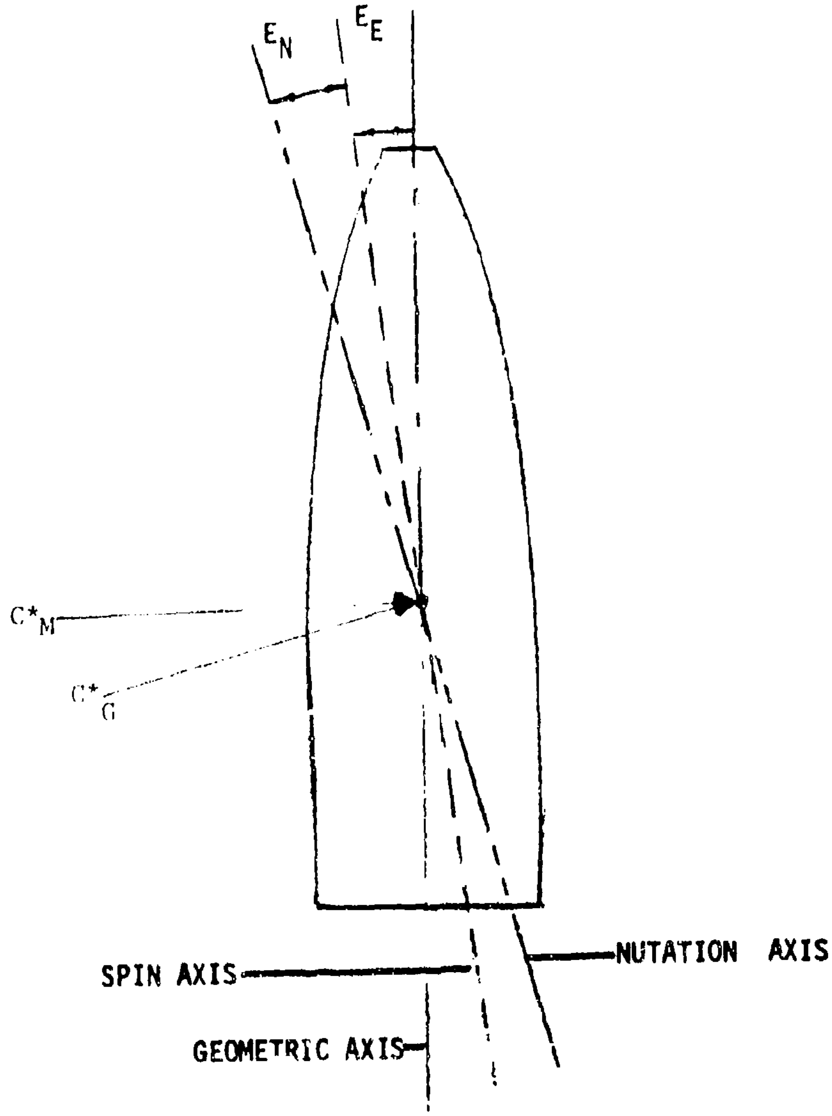
3. clearance between ball rotor and housing and the coefficient of friction

4. a center of gravity eccentricity of the rotor ball

5. drag on the projectile.

Computer simulations of the ball rotor have shown that the spin eccentricity of the projectile is of utmost importance. Spin eccentricity is the tendency of a round to spin about its center of mass rather than its geometric center. This causes eccentricity friction torque. A large projectile eccentricity, for example, could "pin" a ball rotor against its housing. If the rotor contacted a point on the housing close to the polar axis of the ball, the ball probably would never aline (arm). Or, if contact occurred on the transverse axis with a large eccentricity, the ball would act like a disk and snap into alignment.

Projectile eccentricity affects the mean distance and the ratio of arming range limits. Simulation has shown that nutation eccentricity



C^*_M = CENTER OF MASS

C^*_G = GEOMETRIC CENTER

E_E = SPIN ECCENTRICITY

E_N = NUTATION ECCENTRICITY

Figure 1. Significant Euler relations of a spinning projectile

if large enough, could counteract the spin eccentricity effect on the ratio of arming range limits. Since projectile contour and stability affect nutation eccentricity (E_n), arming distances could be influenced by these facts. A tendency toward projectile instability will narrow the arming range and decrease the mean arming distance. Nutation eccentricity is also affected by the clearance and the coefficient of friction between the ball and housing in the fuze. This clearance depends on the tolerances allowed by the technical data package (TDP). The coefficient of friction is a result of material properties and surface finish.

The ball rotor is an inertial device. All inertial devices such as runaway escapements, orifice flow dashpots, and ball rotors, tend to show constant turns-to-arm characteristics, other factors being equal. At any muzzle velocity, a specific ball rotor design in a particular force environment will arm in a constant number of projectile revolutions.

For example, a 20 mm projectile with a ball rotor S&A device would be expected to produce the same arming distance at any muzzle velocity. The same 20 mm fuze in a projectile with different spin and nutation eccentricities would arm in a different number of turns. If projectiles have similar eccentricities, the number of turns-to-arm will also be similar. The rotor ball can be modified to yield any reasonable number of turns-to-arm.

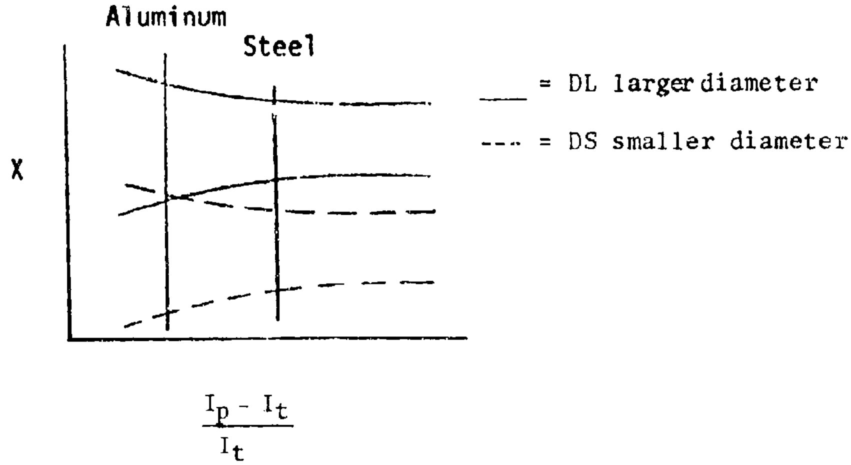
A properly controlled ball rotor will count (arm) in the same number of revolutions when placed in a projectile, regardless of caliber. Therefore, a ball rotor which takes 30 turns to arm will nominally provide a safe separation distance of 50 feet (15.24 meters) for a 20 mm projectile, 119 feet (36.27 meters) for a 40 mm projectile, and 168 feet (51.21 meters) for a 57 mm projectile, if other parameters are unchanged.

It is not expected that the ball rotor S&A which operates successfully in a 20 mm projectile would work as well in eight inch (196 mm) artillery. A 40 mm projectile has larger eccentricities than a 20 mm projectile and could require the use of buoyant forces in the ball to reduce the ball's effective mass.

Correlations

Computer studies have indicated the relation shown in figure 2. This figure reveals that the non-arming distances of lightweight, small-diameter rotor balls are less than those of heavier, larger diameter rotor balls. As the effective mass (M_e) of the rotor ball decreases, the arming range diverges. The best ball rotor designs maximize the difference between the polar and transverse moments of inertia.

The Time Step Simulation mathematical model revealed that when the maximum arming distance of a ball rotor fuze is increased, the range becomes larger but the ratio of extreme points remains approximately the same. For example, if a ball rotor S&A system demonstrated a range from



x = arming distance
I_p = polar moment of inertia, rotor ball
I_t - transverse moment of inertia, rotor ball

Figure 2. Moment of inertia ratio of a ball rotor versus arming distance at different ball densities

10 to 30 feet (3.0 to 9.144 meters), a 3:1 ratio, a similar system with a minimum of 50 feet (15.25 meters) would normally have a maximum limit of 150 feet (45.72 meters) maintaining the 3:1 ratio. This is a criterion for a discrete arming dispersion and is referred to by the designer who wishes to manipulate the arming range and determine if he has a normal, controllable system.

A flotation fluid could be used to improve the arming distance dispersion. The following relation indicates that the presence of the liquid reduces the effective mass of the ball, diminishing the frictional forces. The effective mass (M_e) is also related to the moments of inertia of the projectile (I_p, I_t), (see equation 7).

$N \propto M$ (by equations 5 and 6)

N = frictional torque

M_e = effective mass of rotor ball.

The mathematical model revealed that, for the dual safe 57 mm fuze, the M_e is reduced and the 100% non-arming (safe) distance increased. An M_e of 1.01 grams produced a 68.79 foot minimum arming distance, using a ball with an M_e of 27.6 grams (a system without the fluid) resulted in a 37.57 foot (11.45 meters) minimum arming distance. See the time step simulation computer program output in appendix A.

Fluid use is predicated on space constraints of the fuze configuration itself. Fluid use was necessary to satisfy allowances to extend the minimum arming distance and retain a narrow dispersion. If the allowances were relaxed, a dry ball rotor system could be developed which would equal the performance characteristics of the "wet" system.

EXPERIMENTAL RESULTS

Procedure

During the first experimental phase, a single safe S&A device similar to the one in the 20 mm M505A2 fuze was examined (fig. 3). This device with a single safety interlock (fig. 4) was placed into fuze parts normally fitted to 20 mm, 40 mm and 57 mm high-velocity projectiles. During the second phase, a double interlock (figs. 5,6) was added to the device and it was installed in a 57 mm round with the components from the M503A2 fuze, which normally has a ball rotor S&A device (fig. 7). Developmental details can be found in reference 1.

Statistical methods were used to delineate the arming characteristics derived from the ballistic test results. The One-Shot Transform Response (OSTR) sensitivity approach was selected (ref. 2) because this strategy is highly reliable and rates a high confidence level from a limited number of responses (tests). The feasibility of using a fluid-immersed single safe S&A device was initially demonstrated by a series of live firings with the inexpensive 20 mm M505A3 fuze hardware. Further work on this fuze was conducted by another agency (ref. 3). Afterwards, higher caliber projectile carriers were used. These ballistic tests were initially conducted with inert fuzes in conjunction with a flash x-ray detection system to determine the ball rotor angular orientation. Later explosive reports from loaded fuzes substantiated the inert test findings.

Single Safe Fuze

Test results of the single safe S&A device in M533 fuze parts affixed to the M383, 40 mm high velocity projectile indicated that it required 8.3 turns to arm at a minimum arming distance of 29.2 feet (8.9 meters), (see table 1 and fig. 8). The single safety model tested in the 57 mm, M306A1 projectile, M503A2 fuze system required 6.5 turns at a 34.3 foot (10.36 meters) distance, see table 2, fig 8. The rotor ball immersed in the dibromomethane flotation fluid was made of nylon and had a steel band around its circumference. The specific gravity of the 40 mm rotor ball was 3.70 and the 57 mm rotor ball 3.5. Both ball diameters were a nominal .499 inches (1.267 cm) (fig. 9).

Dual Safe Fuzes

The dual safe 57 mm fuze had a Teflon coated steel ball with a specific gravity of 6.67 and diameter of .375 inches (.953 cm) (see

fig. 10). The ball was placed in the pocket of a nylon centering ring (fig. 6). The Teflon-coated rotor ball is immersed in dibromomethane, a high-density, low-viscosity fluid. The nylon centering ring alines itself on the spin axis of the projectile because its density is less than the density of the dibromomethane fluid.

Centering the ball rotor on the spin axis tends to decrease eccentricity effects. The sequence of operation of the dual safe ball rotor module (fig. 11) relates each component with the flotation fluid. During setback (launch of projectile) the plastic centering ring moves forward against a bias spring (fig. 12) because it is more dense than the immersion fluid. The centering ring and rotor housing remove a lock directly on the ball rotor and release the spin detents (fig. 5), allowing them to move out under the action of spin (centrifugal force) removing both safety interlocks. The Teflon-coated steel ball rotates to aline its detonator with the other portions of the explosive train.

The projectile impacts the target, pushing the firing pin (fig. 13) through a thin aluminum membrane into the fluid filled cavity, striking the rotor ball detonator (fig. 14). The detonator's energy is transferred out of the confined housing cavity and into the relay (fig. 15) which, in turn, ignites a booster pellet (fig. 16) at the base of the fuze. The experimental dual safe 57 mm fuze was monitored by two x-ray cameras which panned perpendicular planes of the projectile. These cameras were positioned at the selected arming distance from the muzzle according to the OSTR strategy. A tungsten disc was placed at each end of the rotor ball cavity that usually contained the detonator. The same mass and moment of inertia of a normally loaded rotor ball was maintained. The projectile impacted a sand pit after being scanned by the x-rays. Arming was determined by the angular orientation of the discs as seen on the x-ray film. The S&A module could be retrieved and examined for anomalies. As a result, less time was required between tests, which hastened the development of a viable device.

A limitation using radiographic methods with the available roentgen levels and tungsten discs in the ball rotor detonator cavity is illustrated by figure 17 and tables 3, 4 and 5. The item depicted on this plot is the dual safe experimental 57 mm S&A module, with a centering ring, housed in standard M503A2 fuze components. The single safe 40 mm and 57 mm S&A mechanisms without a centering ring had components altered for x-ray clarity. The detonator on each caliber round was replaced by a hollow copper sleeve (fig. 18). The 40 mm item's ogive was partially made of lexan (figs. 19, 20) The 57 mm S&A device had a partially narrowed ball rotor housing (figs. 21, 22).

A ball rotor was considered armed when its polar axis varied 12 degrees or less from coincidence with the projectile's polar axis. Some x-rays showed the ball's axis at the outer limit. The outline of the tungsten discs on the x-ray film was not precise. Therefore three possible interpretations of the hard plate x-rays arose producing the three illustrated maximum likelihood curves on figure 17. They have

similar slopes but different safe arm distances. At a probability of 1% and a 95% confidence level, the arming distances were 26.94, 43.36 or 47.02 feet (8.21, 13.22 or 14.33 meters). Explosive ballistic firings conducted after the flash x-rays tests, indicated that the 26.94 feet (8.21 meters) distance was the most appropriate selection (fig. 23). These "live" firings used an S&A device contained in the M550 fuze contour (fig. 23) essentially identical to that used in the x-ray tests of the M503A2 fuze shape (fig. 24).

The surface of both nylon centering rings' pocket, which housed the rotor ball, had a surface finish left by the machining tool. The arming ranges were 26.94 to 83.44 feet (8.21 to 25.43 meters) and 30.93 to 109.41 feet (9.43 to 33.35 meters), tables 5, 6 and figure 25, producing ratios of 3.10:1 versus 3.54:1 which indicated an area needing improvement.

Two groups of "live" fuzes were tested using the OSTR strategy. The groups were divided according to the surface finish of the centering ring pocket and the ogive shape. One group had the M550 fuze (40 mm) ogive (fig. 26), a thin-skinned aluminum hemispherical cup, fitted onto a truncated portion of the M503A2 fuze ogive (fig. 27). The surface finish of its centering ring was made with a machining tool (fig. 23). The other group had the standard M503A2 fuze (57 mm) ogive, which has a thick conical shaped skin (fig. 28). The surface on its centering ring's pocket was polished (fig. 24).

The "Weight" Computer Program (ref. 4) derived stability factors of 2.32 (57 mm ogive) and 2.45 (40 mm ogive). (See Weight Computer Program, appendix B) Stability factors of 1.5 to 2.5, inclusive, are acceptable. The mean arming distances were 68.5 feet (20.82 meters) (57 mm ogive) and 61.25 feet (18.67 meters) (40 mm ogive). The minimum arming distances were 30.93 feet (9.43 meters) (40 mm ogive) and 50.0 feet (15.24 meters) (57 mm ogive). (See tables 6, 7 and fig. 29). These results confirmed that the coefficient of friction on the surface of the centering ring's pocket had a marked influence on the performance characteristics.

Spin eccentricity would produce a similar arming range pattern, but testing strategy, design and round similarity would obscure this effect when correlating test results. The fuze contour had little or no influence as both the arming distance and the ratio of arming range limits changed (table 8).

Shape variations of the 57 mm fuze using the "Spin 73" Computer Program (ref. 5) indicated significant variations of the stability factors which could influence the arming range and mean arming distance. (See Spin 73 Computer Program, appendix C).

The effect of using a rotor ball with a centering ring in achieving dual safety is illustrated by the following: the 57 mm projectile was tested with a dual and a single safety S&A device previously described. The OSTR strategy was stressed to the safe arming point. The maximum

likelihood arming limits of 117 and 87.22 feet (35.66 and 26.58 meters) divided by 50 and 34.3 feet (15.24 and 10.45 meters) resulted in a factor of 2.34 for the experimental dual safe and 2.54 for the experimental single safe models (tables 2,7). This comparison is apparently valid because it conforms to the dictates of the computer design aid. The arming point was increased but the ratios of the arming limits were approximately the same. Therefore, it substantiates the use of flash x-rays in lieu of "live" tests in order to indicate feasibility, correct for design and fabrication errors without expending expensive prototype hardware.

Program Verification

All 57 mm projectile tests were conducted with the M306A1 TP round, lot JA-10-12A (fig. 30). Velocity profile monitorings at muzzle distances within the experimental arming range produced a mean velocity of 1170 ft/sec (346.62 m/sec). Although lethal area estimates for this round were not found, Ordnance Committee item 32814, 16 June 1949, referred to a desired delayed arming of 70 feet (21.34 meters) from the weapon, with reliable arming obtained at 100 feet (30.48 meters). These objectives were not obtained; therefore, there existed a need to extend the safe arming distance.

The standard M503A2 fuze with a naval brass ball rotor had undergone a dud rate malfunction investigation. After extensive tests and rigorous in-depth analysis (ref 6, 7 and 8), the rotor ball in the outmoded M503A1 fuze replaced the A2 model ball. A modification to the A2 ball also resolved the failures but "live" ballistic tests, following an OSTR strategy, were less acceptable than those of the A1 ball (M503A2 (A1)), (see tables 9,10 and fig. 31). Test results of the experimental ball rotor fuze and the M503A2(A1) fuze having the same contour were also compared. The experimental design had extended the safe arming distance by twenty feet. At a 1% probability and 95% confidence level, the minimum arming distance was 50 feet (15.24 meters) versus 30 feet (9.14 meters).

A complete overall comparison between the experimental S&A and the standard S&A was not valid because of the different OSTR strategies. The standard fuze stressed functioning reliability while the experimental S&A concentrated on the safe or 100% non-arming distance. The OSTR strategies varied because of the types of programs being conducted, one was a development program and the other a malfunction investigation in which functioning, not safety, was the prime concern. Strict correlations between the upper and lower confidence limits at a particular functioning probability would be misleading.

The OSTR strategies for the experimental S&A device and the two versions of the M503A2, differing in their rotor balls, used 25, 75 and 100, 57 mm rounds, respectively. The Weibull Quantile estimates for the standard version's arming limits were between 30 to 64 feet (9.14

to 19.51 meters) (A1 ball) and 15 to 67 feet (4.57 to 20.42 meters), see table 8. The arming limit ratios of 2:12 and 4:48 indicate that the modification to the A2 ball was not optimized.

The arming range ratios in table 8 indicate that both the experimental ball rotor S&A device and the standard M503A2 with the A1 rotor ball are viable mechanisms. This also conforms to past program observations; as the arming range is extended, the dispersion tends to maintain an approximate 2:1 ratio.

CONCLUSION

This effort has demonstrated that the Ball Rotor "Time Step Simulation" computer program, with the aid of radiographic and analytical testing techniques, is a valuable design and teaching tool. The objective of producing a controllable S&A device when manipulating the arming range of various caliber projectiles was met. The output data from the program reflected actual tendencies of a ball rotor mechanism as discerned by this and other investigators. The experienced designer could use the mathematical model to easily evaluate ball rotor configurations, and the neophyte could get a detailed insight into the complexities of a ball rotor S&A system.

RECOMMENDATION

This CAD-E approach should further be pursued so that the ball rotor will reach its full potential as a simple, inexpensive, safe and reliable safe-and-arming device.

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Table 1. Flash x-ray test, 40 mm single safe experimental S&A device

I	STIMULUS	RESPONSE
1	60.0000	1
2	45.0000	1
3	37.5000	0
4	37.5000	0
5	37.5000	0
6	41.2500	0
7	41.2500	0
8	41.2500	0
9	50.6500	1
10	45.8500	1
11	41.6800	0
12	41.6800	0
13	41.6800	1
14	35.8400	0
15	35.8400	1
16	32.9200	0
17	32.9200	0
18	32.9200	0
19	34.3800	0
20	34.3800	0
21	34.3800	0
22	38.0300	1
23	36.2100	0
24	36.2100	1
25	34.5700	0
26	34.5700	0
27	34.5700	0
28	35.3900	0
29	35.3900	0
30	35.3900	1
31	45.0000	1
32	50.6500	1
33	45.8500	1
34	43.7700	1
35	35.8400	0
36	38.0300	0
37	38.0300	0
38	41.9400	0
39	36.2100	0

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.29199E+02	.95285E+01	.950	.10524E+02	.47875E+02
.0500	.33289E+02	.35396E+01	.950	.26351E+02	.40226E+02
.1000	.35362E+02	.20005E+01	.950	.31441E+02	.39283E+02
.1500	.36698E+02	.16146E+01	.950	.33533E+02	.39862E+02
.2000	.37720E+02	.15662E+01	.950	.34650E+02	.40789E+02
.2500	.38566E+02	.15948E+01	.950	.35441E+02	.41692E+02
.3000	.39303E+02	.16238E+01	.950	.36121E+02	.42486E+02
.4000	.40577E+02	.16294E+01	.950	.37384E+02	.43771E+02
.5000	.41703E+02	.15813E+01	.950	.38604E+02	.44802E+02
.6000	.42769E+02	.15348E+01	.950	.39761E+02	.45777E+02
.7000	.43846E+02	.15807E+01	.950	.40748E+02	.46944E+02
.8000	.45030E+02	.18672E+01	.950	.41370E+02	.48690E+02
.9000	.4[illegible]548E+02	.26726E+01	.950	.41310E+02	.51786E+02
.9500	.47706E+02	.35740E+01	.950	.40701E+02	.54710E+02

Table 2. Flash x-ray test, 57 mm single safe experimental S&A device

I	STIMULUS	RESPONSE
1	100.0000	1
2	100.0000	1
3	100.0000	1
4	100.0000	1
5	60.0000	0
6	60.0000	0
7	60.0000	1
8	45.0000	0
9	45.0000	0
10	45.0000	0
11	52.5000	0
12	52.5000	1
13	52.5000	0
14	48.7500	0
15	48.7500	0
16	48.7500	0
17	50.6200	0
18	50.6200	0
19	50.6200	1
20	49.6800	0
21	49.6800	0
22	49.0000	0
23	50.1500	0
24	50.1500	0
25	50.1500	0
26	75.0750	1
27	75.0750	0
28	75.0750	1

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.34331E+02	.28683E+02	.950	-.21887E+02	.90550E+02
.0500	.43858E+02	.10868E+02	.950	.22558E+02	.65158E+02
.1000	.49177E+02	.58908E+01	.950	.37632E+02	.60723E+02
.1500	.52775E+02	.50988E+01	.950	.42782E+02	.62769E+02
.2000	.55614E+02	.55488E+01	.950	.44739E+02	.66490E+02
.2500	.58925E+02	.61514E+01	.950	.45968E+02	.70081E+02
.3000	.60164E+02	.66551E+01	.950	.47120E+02	.73208E+02
.4000	.63953E+02	.72958E+01	.950	.49653E+02	.78252E+02
.5000	.67396E+02	.75944E+01	.950	.52512E+02	.82281E+02
.6000	.70737E+02	.77599E+01	.950	.55528E+02	.85946E+02
.7000	.74194E+02	.80545E+01	.950	.58407E+02	.89980E+02
.8000	.78084E+02	.89372E+01	.950	.60568E+02	.95601E+02
.9000	.83211E+02	.11542E+02	.950	.60590E+02	.10583E+03
.9500	.87223E+02	.14802E+02	.950	.58211E+02	.11623E+03

Table 3. Flash x-ray test, 57 mm dual safe experimental S&A device

I	STIMULUS	RESPONSE
1	100.0000	1
2	60.0000	0
3	60.0000	0
4	60.0000	0
5	75.0000	1
6	67.5000	0
7	67.5000	0
8	67.5000	0
9	71.2500	0
10	71.2500	0
11	71.2500	1
12	69.3700	1
13	69.3700	0
14	69.3700	0
15	44.6850	0
16	44.6850	0
17	44.6850	0
18	44.6850	0
19	57.0550	0
20	57.0550	0
21	57.0550	0
22	64.1000	0
23	64.1000	1
24	64.1000	0
25	62.5000	1
26	62.5000	0
27	62.5000	1
28	52.6000	0
29	52.6000	0
30	52.6000	0
31	90.0000	1
32	90.0000	1
33	90.0000	1

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.47027E+02	.14729E+02	.950	.18159E+02	.75896E+02
.0500	.55082E+02	.65102E+01	.950	.42322E+02	.67842E+02
.1000	.59176E+02	.43611E+01	.950	.50629E+02	.67724E+02
.1500	.61818E+02	.35982E+01	.950	.54766E+02	.68871E+02
.2000	.63841E+02	.32719E+01	.950	.57428E+02	.70253E+02
.2500	.65518E+02	.31296E+01	.950	.59384E+02	.71652E+02
.3000	.66978E+02	.30841E+01	.950	.60933E+02	.73023E+02
.4000	.69504E+02	.31753E+01	.950	.63280E+02	.75727E+02
.5000	.71738E+02	.34731E+01	.950	.64931E+02	.78545E+02
.6000	.73854E+02	.39919E+01	.950	.66030E+02	.81678E+02
.7000	.75995E+02	.47798E+01	.950	.66626E+02	.85363E+02
.8000	.78349E+02	.59563E+01	.950	.66675E+02	.90023E+02
.9000	.81370E+02	.79182E+01	.950	.65850E+02	.96889E+02
.9500	.83674E+02	.97333E+01	.950	.64597E+02	.10275E+03

Table 4. Flash x-ray test, 57 mm dual safe experimental S&A device

I	STIMULUS	RESPONSE
1	100.0000	1
2	60.0000	0
3	60.0000	1
4	60.0000	0
5	75.0000	1
6	67.5000	1
7	67.5000	0
8	67.5000	1
9	71.2500	0
10	71.2500	0
11	71.2500	1
12	69.3700	1
13	69.3700	0
14	69.3700	1
15	44.6850	0
16	44.6850	0
17	44.6850	0
18	44.6850	0
19	57.0550	0
20	57.0550	0
21	57.0550	0
22	64.1000	1
23	64.1000	1
24	64.1000	0
25	62.5000	1
26	62.5000	0
27	62.5000	1
28	52.6000	0
29	52.6000	0
30	52.6000	0
31	90.0000	1
32	90.0000	1
33	90.0000	1

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.43365E+02	.13743E+02	.950	.16430E+02	.70300E+02
.0500	.49512E+02	.68177E+01	.950	.36149E+02	.62874E+02
.1000	.53060E+02	.48124E+01	.950	.43628E+02	.62493E+02
.1500	.55501E+02	.40568E+01	.950	.47550E+02	.63452E+02
.2000	.57449E+02	.36828E+01	.950	.50231E+02	.64667E+02
.2500	.59116E+02	.34486E+01	.950	.52357E+02	.65875E+02
.3000	.60606E+02	.32705E+01	.950	.54196E+02	.67016E+02
.4000	.63268E+02	.29912E+01	.950	.57405E+02	.69130E+02
.5000	.65710E+02	.28351E+01	.950	.60154E+02	.71267E+02
.6000	.68100E+02	.29414E+01	.950	.62335E+02	.73865E+02
.7000	.70593E+02	.35079E+01	.950	.63718E+02	.[illegible]7469E+02
.8000	.73423E+02	.47532E+01	.950	.64107E+02	.82739E+02
.9000	.77187E+02	.72137E+01	.950	.63049E+02	.91326E+02
.9500	.80160E+02	.96660E+01	.950	.61215E+02	.99105E+02

Table 5. Flash x-ray test, 57 mm dual safe experimental S&A device

I	STIMULUS	RESPONSE
1	100.0000	1
2	60.0000	0
3	60.0000	0
4	60.0000	0
5	75.0000	1
6	67.5000	0
7	67.5000	0
8	67.5000	0
9	71.2500	0
10	71.2500	0
11	71.2500	1
12	69.3700	1
13	69.3700	0
14	69.3700	0
15	44.6850	0
16	44.6850	0
17	44.6850	0
18	44.6850	0
19	57.0550	0
20	57.0550	0
21	57.0550	0
22	64.1000	0
23	64.1000	1
24	64.1000	0
25	62.5000	1
26	62.5000	0
27	62.5000	1
28	52.6000	0
29	52.6000	0
30	52.6000	0
31	90.0000	1
32	90.0000	1
33	90.0000	1

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.47027E+02	.14729E+02	.950	.18159E+02	.75896E+02
.0500	.55082E+02	.65102E+01	.950	.42322E+02	.67842E+02
.1000	.59176E+02	.43611E+01	.950	.50629E+02	.67724E+02
.1500	.61818E+02	.35982E+01	.950	.54766E+02	.68871E+02
.2000	.63841E+02	.32719E+01	.950	.57428E+02	.70253E+02
.2500	.65518E+02	.31296E+01	.950	.59384E+02	.71652E+02
.3000	.66978E+02	.30841E+01	.950	.60933E+02	.73023E+02
.4000	.69504E+02	.31753E+01	.950	.63280E+02	.75727E+02
.5000	.71738E+02	.34731E+01	.950	.64931E+02	.78545E+02
.6000	.73854E+02	.39919E+01	.950	.66030E+02	.81678E+02
.7000	.75995E+02	.47798E+01	.950	.66626E+02	.85363E+02
.8000	.78349E+02	.59563E+01	.950	.66675E+02	.90023E+02
.9000	.81370E+02	.79182E+01	.950	.65850E+02	.96889E+02
.9500	.83674E+02	.97333E+01	.950	.64597E+02	.10275E+03

Table 6. Explosive output test, 57 mm dual safe experimental S&A device

I	STIMULUS	RESPONSE
1	85.0000	1
2	67.5000	1
3	58.7000	1
4	54.4000	1
5	40.0000	0
6	40.0000	0
7	40.0000	0
8	47.2000	0
9	47.2000	1
10	43.6000	0
11	43.6000	0
12	43.6000	0
13	45.4000	1
14	44.5000	0
15	44.5000	0
16	44.5000	0
17	45.0000	0
18	45.0000	1
19	45.0000	0
20	45.0000	1
21	70.0000	1
22	70.0000	1
23	70.0000	0
24	85.0000	0
25	92.5000	0
26	100.0000	1
27	100.0000	1
28	100.0000	1
29	96.2500	1
30	96.2500	1
31	96.2500	1
32	94.1700	1
33	94.1700	1
34	94.1700	1
35	85.0000	1

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.30933E+02	.32347E+02	.950	-.32466E+02	.94332E+02
.0500	.33326E+02	.22789E+02	.950	-.11339E+02	.77991E+02
.1000	.35832E+02	.15814E+02	.950	.48367E+01	.66827E+02
.1500	.38177E+02	.10916E+02	.950	.16783E+02	.59572E+02
.2000	.40472E+02	.74124E+01	.950	.25944E+02	.55000E+02
.2500	.42767E+02	.53676E+01	.950	.32246E+02	.53287E+02
.3000	.45098E+02	.50799E+01	.950	.35141E+02	.55054E+02
.4000	.49986E+02	.74766E+01	.950	.35326E+02	.64634E+02
.5000	.55351E+02	.10059E+02	.950	.35636E+02	.75066E+02
.6000	.61517E+02	.11680E+02	.950	.38624E+02	.84409E+02
.7000	.68998E+02	.12125E+02	.950	.45234E+02	.92763E+02
.8000	.78908E+02	.12009E+02	.950	.55371E+02	.10244E+03
.9000	.94671E+02	.18175E+02	.950	.59048E+02	.13029E+03
.9500	.10941E+03	.33098E+02	.950	.44537E+02	.17428E+03

Table 7. Explosive output test 57 mm dual safe experimental S&A device

I	STIMULUS	RESPONSE
1	47.5000	0
2	47.5000	0
3	47.5000	0
4	51.2500	0
5	51.2500	0
6	51.2500	0
7	51.8300	0
8	51.8300	0
9	51.8300	0
10	52.4100	0
11	52.4100	1
12	53.5800	0
13	53.5800	0
14	53.5800	1
15	55.0000	1
16	55.9200	0
17	55.9200	0
18	55.9200	1
19	58.0000	0
20	58.0000	1
21	60.6000	1
22	64.0000	0
23	70.0000	0
24	70.0000	1
25	85.0000	1

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.50036E+02	.52606E+01	.950	.39726E+02	.60347E+02
.0500	.50312E+02	.41290E+01	.950	.42219E+02	.58404E+02
.1000	.50807E+02	.28556E+01	.950	.45210E+02	.56404E+02
.1500	.51430E+02	.19492E+01	.950	.47609E+02	.55250E+02
.2000	.52173E+02	.17329E+01	.950	.48776E+02	.55569E+02
.2500	.53038E+02	.21859E+01	.950	.48754E+02	.57323E+02
.3000	.54036E+02	.28700E+01	.950	.48411E+02	.59661E+02
.4000	.56485E+02	.42068E+01	.950	.48239E+02	.64730E+02
.5000	.59703E+02	.55958E+01	.950	.48735E+02	.70670E+02
.6000	.64026E+02	.83156E+01	.950	.47727E+02	.80324E+02
.7000	.70114E+02	.14966E+02	.950	.40781E+02	.99446E+02
.8000	.79507E+02	.30126E+02	.950	.20460E+02	.13855E+03
.9000	.97346E+02	.68840E+02	.950	-.37577E+02	.23227E+03
.9500	.11702E+03	.12112E+03	.950	-.12038E+03	.35441E+03

Table 8. *Arming range limits*

Table 8. Arming range limits

TEST ITEM	TEST TYPE	ARMING RANGE (FT) WEIBULL QUANTILE ESTIMATES	ARMING RANGE RATIO
57mm, M306A1 TD Cartridge M503A2 Fuze M503A1 Fuze Naval Brass ~~Ball~~ Rotor	Explosive ballistic	30-64	2.1:1
57mm, M306A1 TP Cartridge, M503A2 Fuze, with a modified M503A2 Naval Brass Ball Rotor	Explosive ballistic	15-67	4.5:1
57mm, M306A1, TP Cartridge, M503A2 ogive, dual safe experimental S&A device, fluid immersed teflon coated steel ball rotor, polished surface nylon centering ring pocket.	Explosive ballistic	50-117	2.3:1
57mm, M306A1 TP Cartridge, M503A2 ogive, dual safe experimental S&A device, fluid immersed teflon coated steel ball rotor, machine tool finish nylon centering ring pocket.	Flash x-ray ballistic	27-83	3.1:1
57mm, M306A1 TP Cartridge, M550 ogive (40mm fuze), dual safe experimental S&A device, fluid immersed teflon coated steel ball rotor, machine tool finish nylon centering ring pocket.	Explosive ballistic	31-109	3.5:1
57mm, M306A1, TP Cartridge, M503A2 ogive, single safe experimental S&A device fluid immersed nylon/steel band ball rotor.	Flash x-ray ballistic	34-87	2.54:1
40mm, M383 Cartridge, M533 ogive, single safe, experimental S&A device fluid immersed nylon/steel band ball rotor.	Flash x-ray ballistic	29-48	1.66:1

Table 9. Explosive output test, 57 mm standard
M503A2 fuze with Al model rotor ball

I	STIMULUS	RESPONSE	I	STIMULUS	RESPONSE
1	50.0000	1	51	83.0000	1
2	50.0000	1	52	68.8000	1
3	50.0000	1	53	68.8000	1
4	50.0000	1	54	68.8000	1
5	50.0000	1	55	68.8000	1
6	50.0000	1	56	68.8000	1
7	25.0000	0	57	68.8000	1
8	37.5000	0	58	60.3000	1
9	68.7500	1	59	60.3000	1
10	68.7500	1	60	60.3000	1
11	68.7500	1	61	60.3000	1
12	68.7500	1	62	60.3000	1
13	68.7500	1	63	60.3000	1
14	68.7500	1	64	49.7000	1
15	53.1300	1	65	49.7000	1
16	53.1300	1	66	49.7000	1
17	53.1300	1	67	49.7000	1
18	53.1300	1	68	49.7000	1
19	53.1300	1	69	49.7000	1
20	53.1300	1	70	24.9000	0
21	39.0700	1	71	37.3000	1
22	39.0700	1	72	37.3000	1
23	39.0700	0	73	37.3000	1
24	46.1000	1	74	37.3000	1
25	46.1000	0	75	37.3000	1
26	57.4300	1	76	37.3000	1
27	57.4300	1	77	31.1000	0
28	57.4300	1	78	34.2000	1
29	57.4300	1	79	34.2000	0
30	57.4300	1	80	47.3000	1
31	57.4300	1	81	47.3000	1
32	51.7700	1	82	47.3000	1
33	51.7700	1	83	47.3000	0
34	51.7700	1	84	58.1000	0
35	51.7700	1	85	75.5000	1
36	51.7700	0	86	75.5000	1
37	54.6000	1	87	75.5000	1
38	54.6000	0	88	75.5000	1
39	77.3000	0	89	75.5000	1
40	88.7000	1	90	75.5000	1
41	88.7000	1	91	66.8000	1
42	88.7000	1	92	66.8000	1
43	88.7000	1	93	66.8000	1
44	88.7000	1	94	66.8000	1
45	88.7000	1	95	66.8000	1
46	83.0000	1	96	66.8000	1
47	83.0000	1	97	57.1000	1
48	83.0000	1	98	57.1000	1
49	83.0000	1	99	57.1000	1
50	83.0000	1	100	57.1000	1

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.30002E+02	.47068E+01	.950	.20777E+02	.39228E+02
.0500	.30036E+02	.46000E+01	.950	.21021E+02	.39052E+02
.1000	.30122E+02	.43957E+01	.950	.21507E+02	.38737E+02
.1500	.30253E+02	.41447E+01	.950	.22129E+02	.38376E+02
.2000	.30430E+02	.38642E+01	.950	.22857E+02	.38004E+02
.2500	.30659E+02	.35682E+01	.950	.23666E+02	.37653E+02
.3000	.30946E+02	.32725E+01	.950	.24532E+02	.37360E+02
.4000	.31729E+02	.27696E+01	.950	.26301E+02	.37157E+02
.5000	.32887E+02	.25922E+01	.950	.27806E+02	.37968E+02
.6000	.34613E+02	.29362E+01	.950	.28858E+02	.40368E+02
.7000	.37297E+02	.36928E+01	.950	.30060E+02	.44535E+02
.8000	.41882E+02	.45237E+01	.950	.33015E+02	.50748E+02
.9000	.51683E+02	.54811E+01	.950	.40940E+02	.62425E+02
.9500	.63733E+02	.97268E+01	.950	.44669E+02	.82798E+02

Table 10. Explosive output test, 57mm standard M503A2 fuze with modified rotor ball

I	STIMULUS	RESPONSE	I	STIMULUS	RESPONSE
1	50.0000	0	39	56.6500	1
2	75.0000	1	40	56.6500	1
3	75.0000	1	41	56.6500	0
4	75.0000	1	42	70.0000	1
5	75.0000	1	43	70.0000	1
6	75.0000	1	44	70.0000	1
7	75.0000	1	45	70.0000	1
8	62.5000	1	46	70.0000	1
9	62.5000	1	47	70.0000	1
10	62.5000	1	48	63.3000	1
11	62.5000	1	49	63.3000	1
12	62.5000	1	50	63.3000	1
13	62.5000	1	51	63.3000	1
14	31.2500	1	52	63.3000	1
15	31.2500	1	53	63.3000	1
16	31.2500	0	54	55.7000	1
17	46.9000	0	55	55.7000	1
18	61.0000	0	56	55.7000	1
19	105.5000	1	57	55.7000	1
20	105.5000	1	58	55.7000	1
21	105.5000	1	59	55.7000	1
22	105.5000	1	60	27.9000	0
23	105.5000	1	61	41.8000	1
24	105.5000	1	62	41.8000	1
25	83.2500	1	63	41.8000	0
26	83.2500	1	64	52.5000	1
27	83.2500	1	65	52.5000	1
28	83.2500	1	66	52.5000	1
29	83.2500	1	67	52.5000	0
30	83.2500	1	68	61.2000	0
31	65.1000	1	69	83.4000	1
32	65.1000	1	70	83.4000	1
33	65.1000	1	71	83.4000	1
34	65.1000	1	72	83.4000	1
35	65.1000	1	73	83.4000	1
36	65.1000	1	74	83.4000	1
37	48.2000	1	75	83.4000	1
38	48.2000	0	76	83.4000	1

WEIBULL QUANTILE ESTIMATES

P	L(P)	SIG LP	C COEF	LCL	UCL
.0100	.14954E+02	.32105E+02	.950	-.47970E+02	.77878E+02
.0500	.19963E+02	.21007E+02	.950	-.21210E+02	.61135E+02
.1000	.23563E+02	.15399E+02	.950	-.66187E+01	.53745E+02
.1500	.26332E+02	.12069E+02	.950	.26765E+01	.49987E+02
.2000	.28709E+02	.97990E+01	.950	.95030E+01	.47914E+02
.2500	.30861E+02	.81766E+01	.950	.14835E+02	.46887E+02
.3000	.32874E+02	.70105E+01	.950	.19134E+02	.46614E+02
.4000	.36681E+02	.56416E+01	.950	.25624E+02	.47739E+02
.5000	.40410E+02	.50980E+01	.950	.30418E+02	.50402E+02
.6000	.44274E+02	.49301E+01	.950	.34611E+02	.53937E+02
.7000	.48529E+02	.48031E+01	.950	.39115E+02	.57943E+02
.8000	.53633E+02	.45064E+01	.950	.44801E+02	.62466E+02
.9000	.60873E+02	.42411E+01	.950	.52560E+02	.69185E+02
.9500	.66946E+02	.52940E+01	.950	.56570E+02	.773[illegible]3E+02

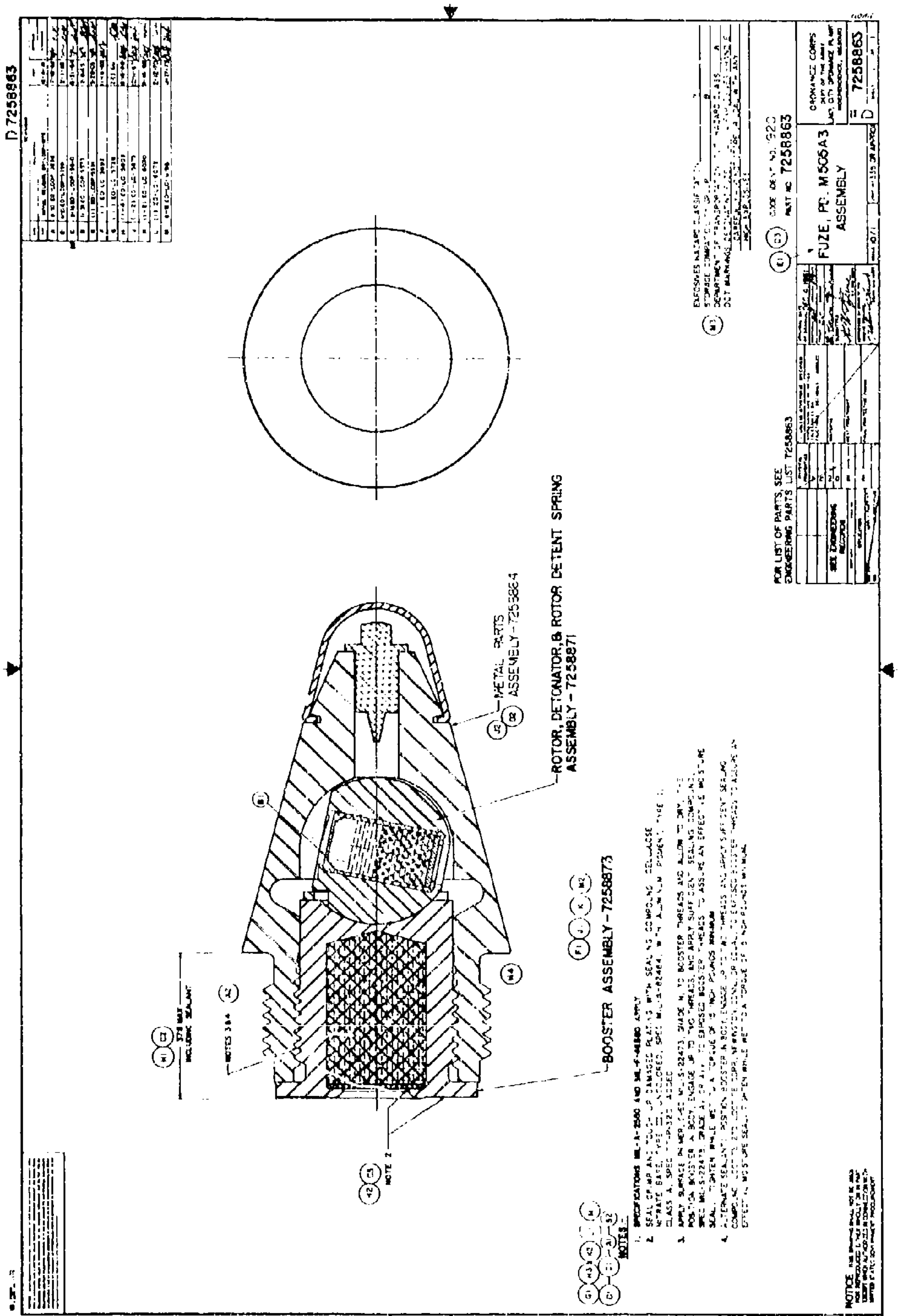

Figure 3. M505A3 fuze

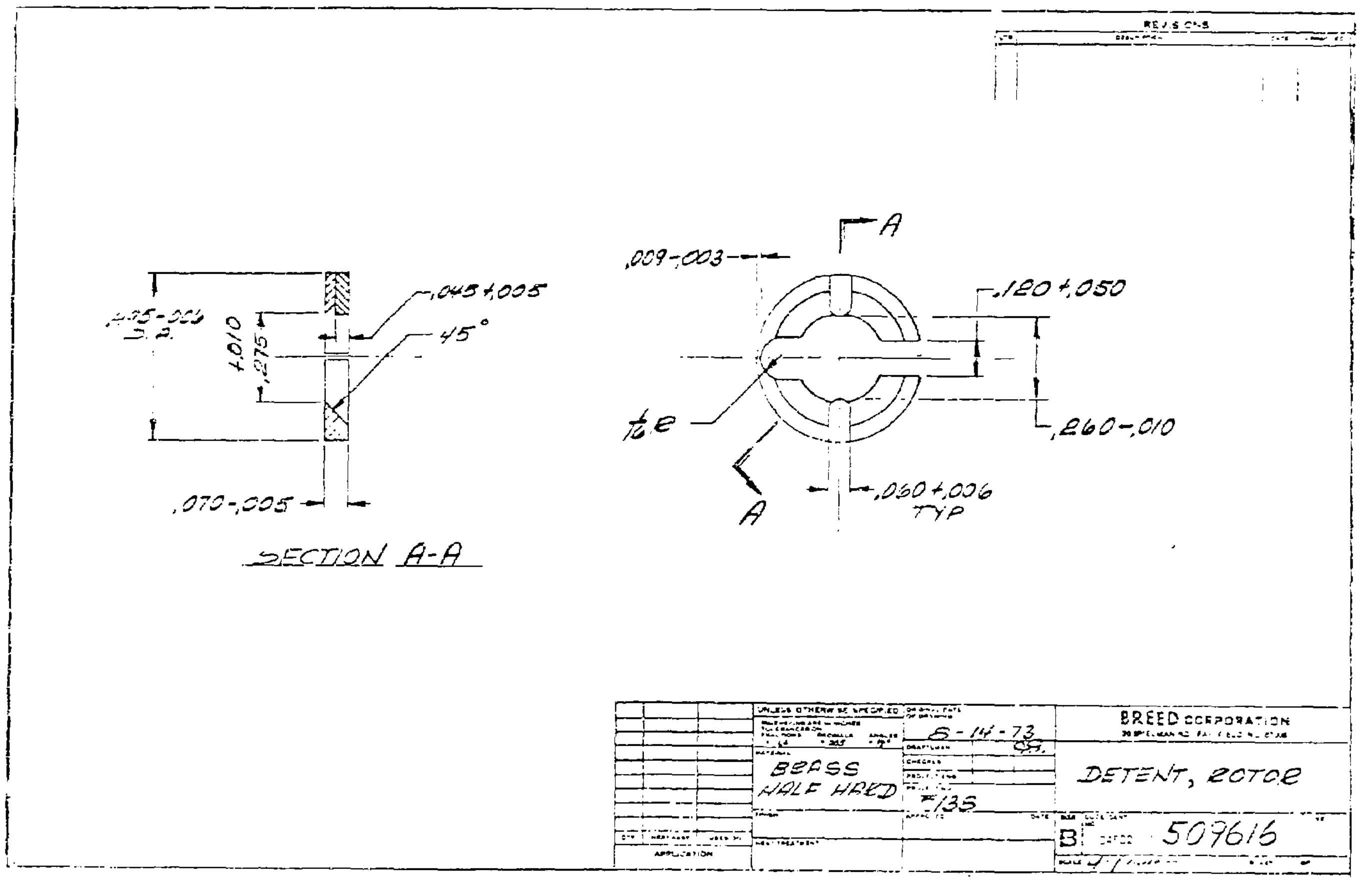

Figure 4. Rotor detent safety interlock used in single safe fuze

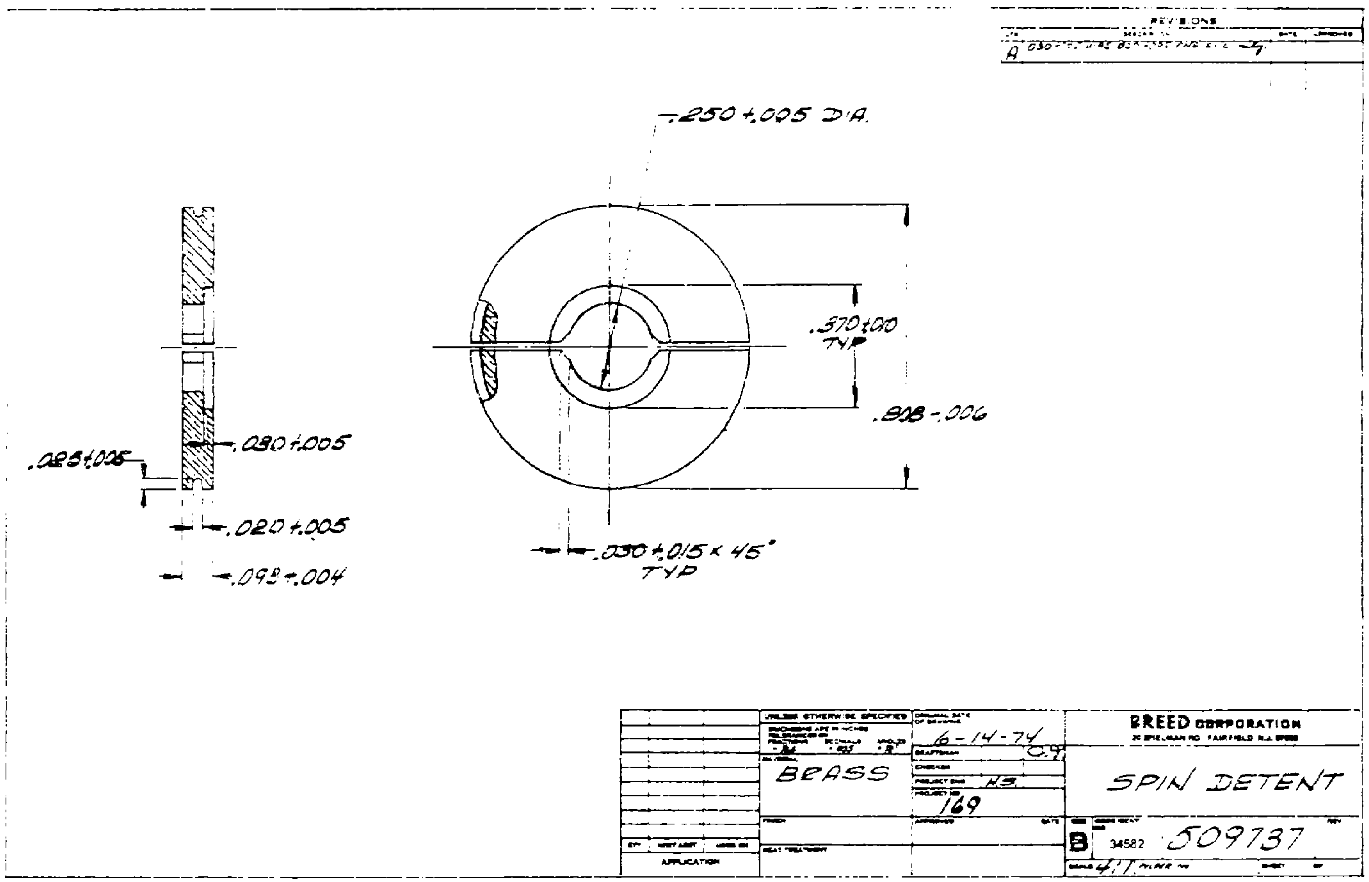

Figure 5. Spin detent used in dual safe S&A device

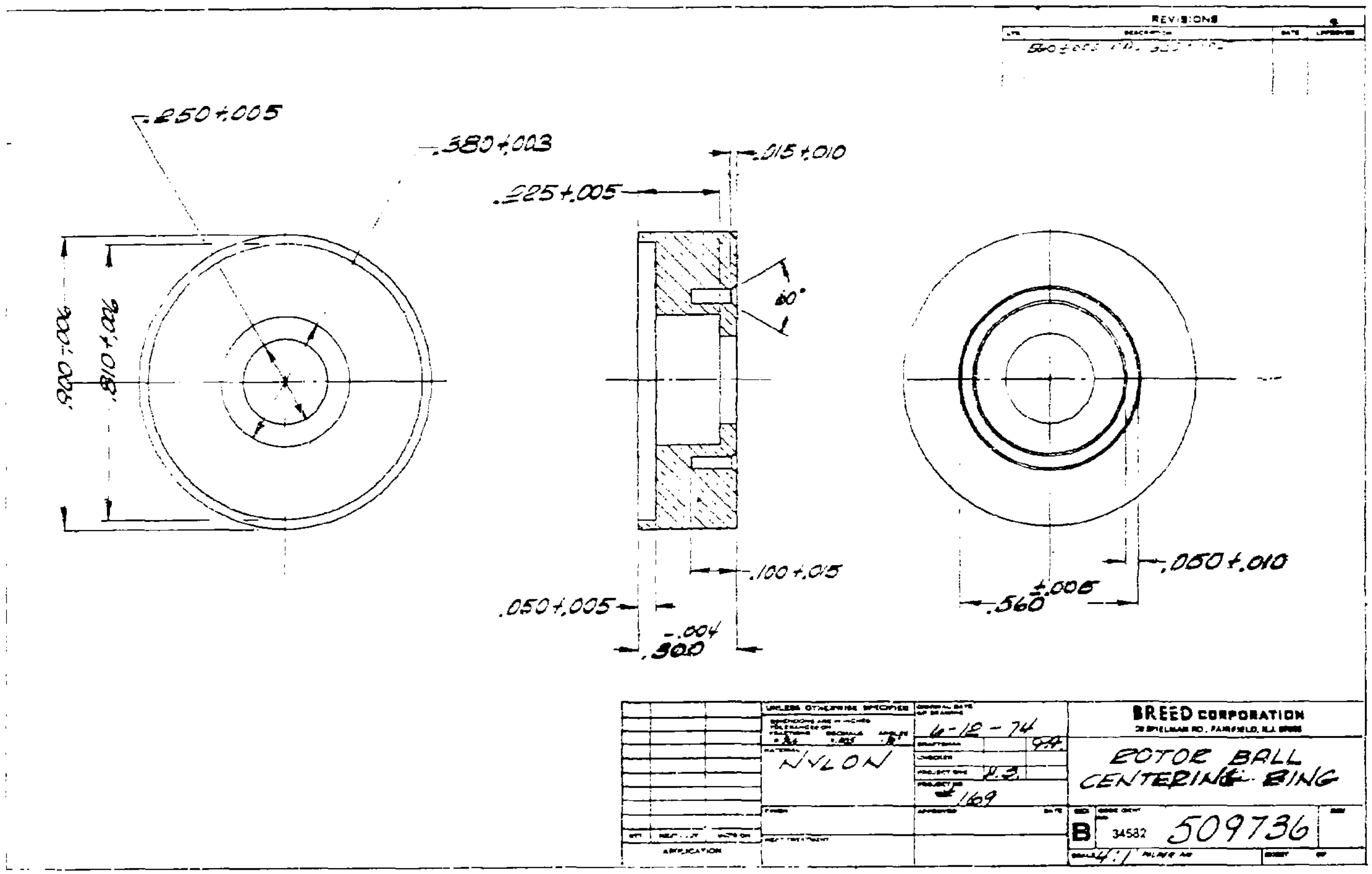

Figure 6. Rotor ball centering ring for dual safe S&A device

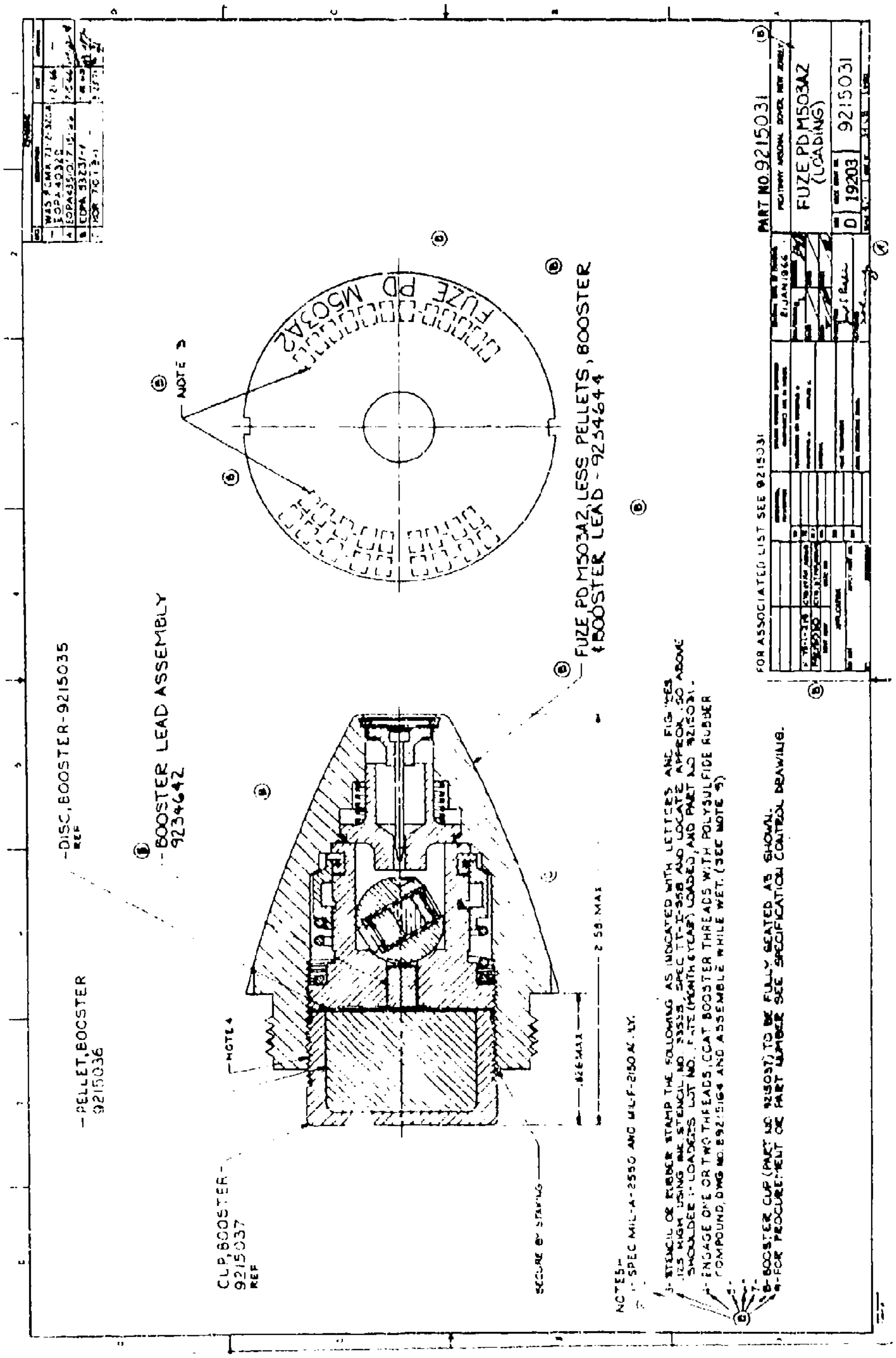

Figure 7. M503A2 fuze

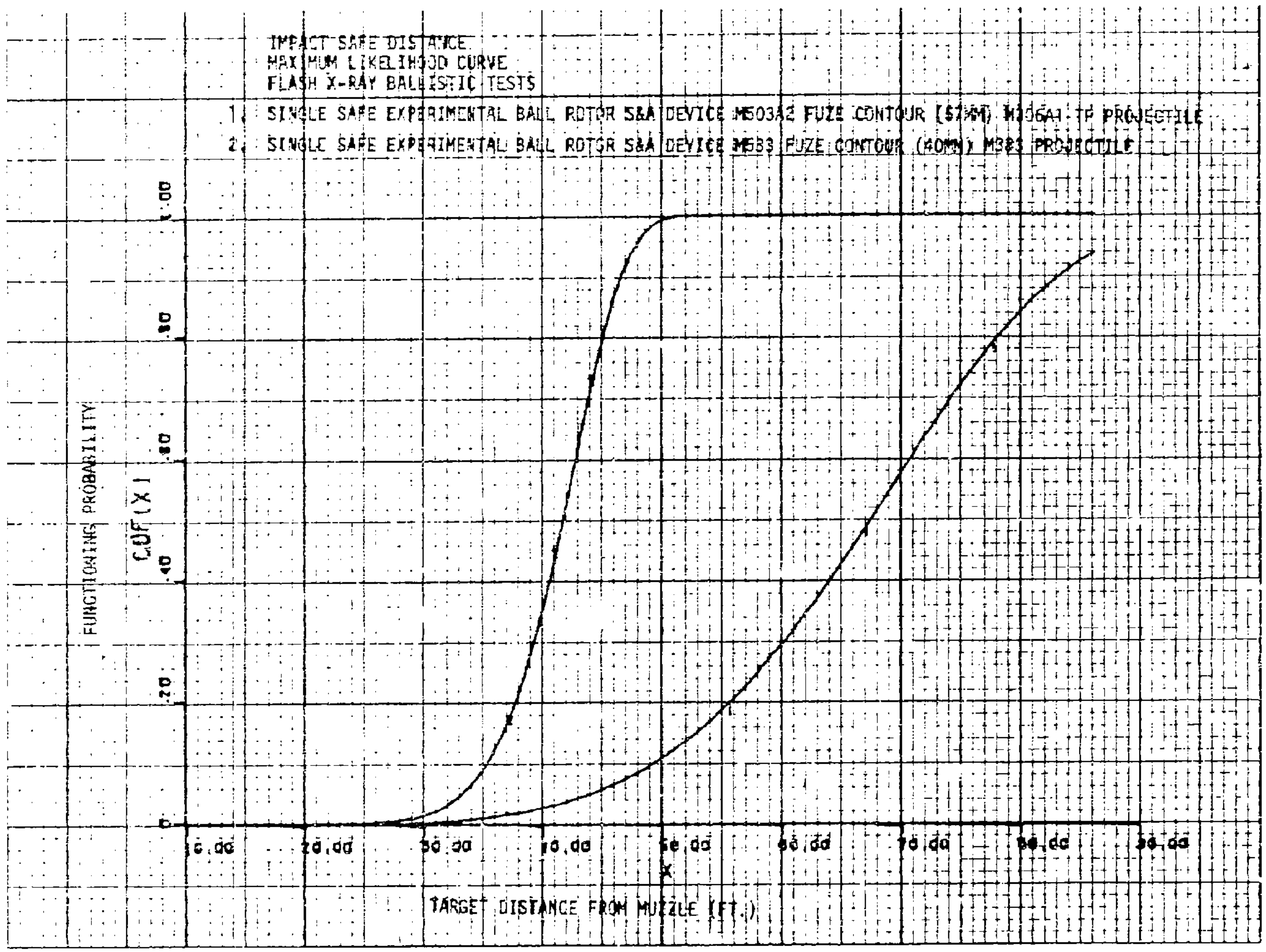

Figure 8. Plot of maximum likelihood curve, single safe experimental ball rotor S&A devices M503A2 and M533

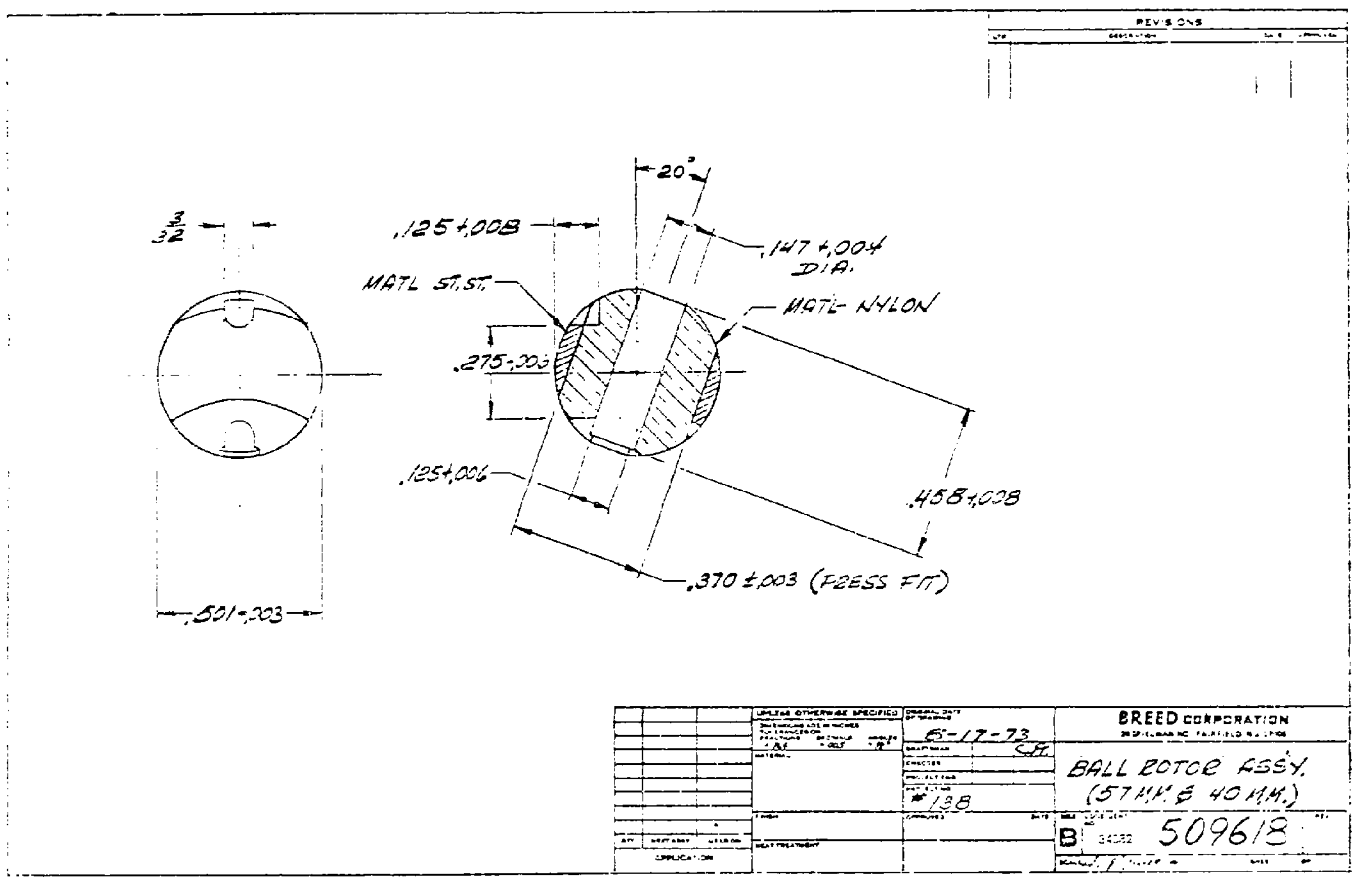

Figure 9. Ball rotor assembly, single safe S&A device

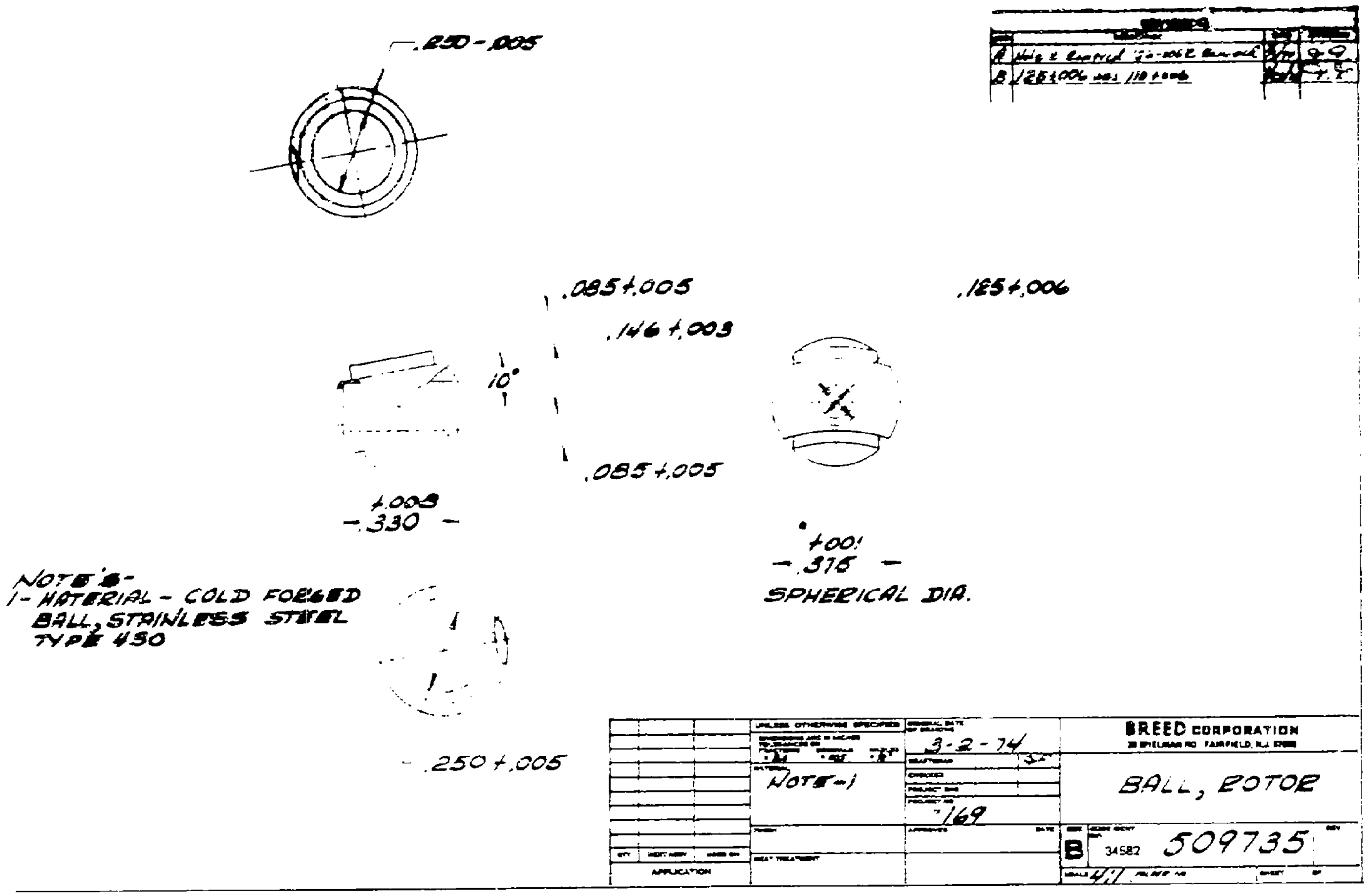

Figure 10. Rotor ball for dual S&A device

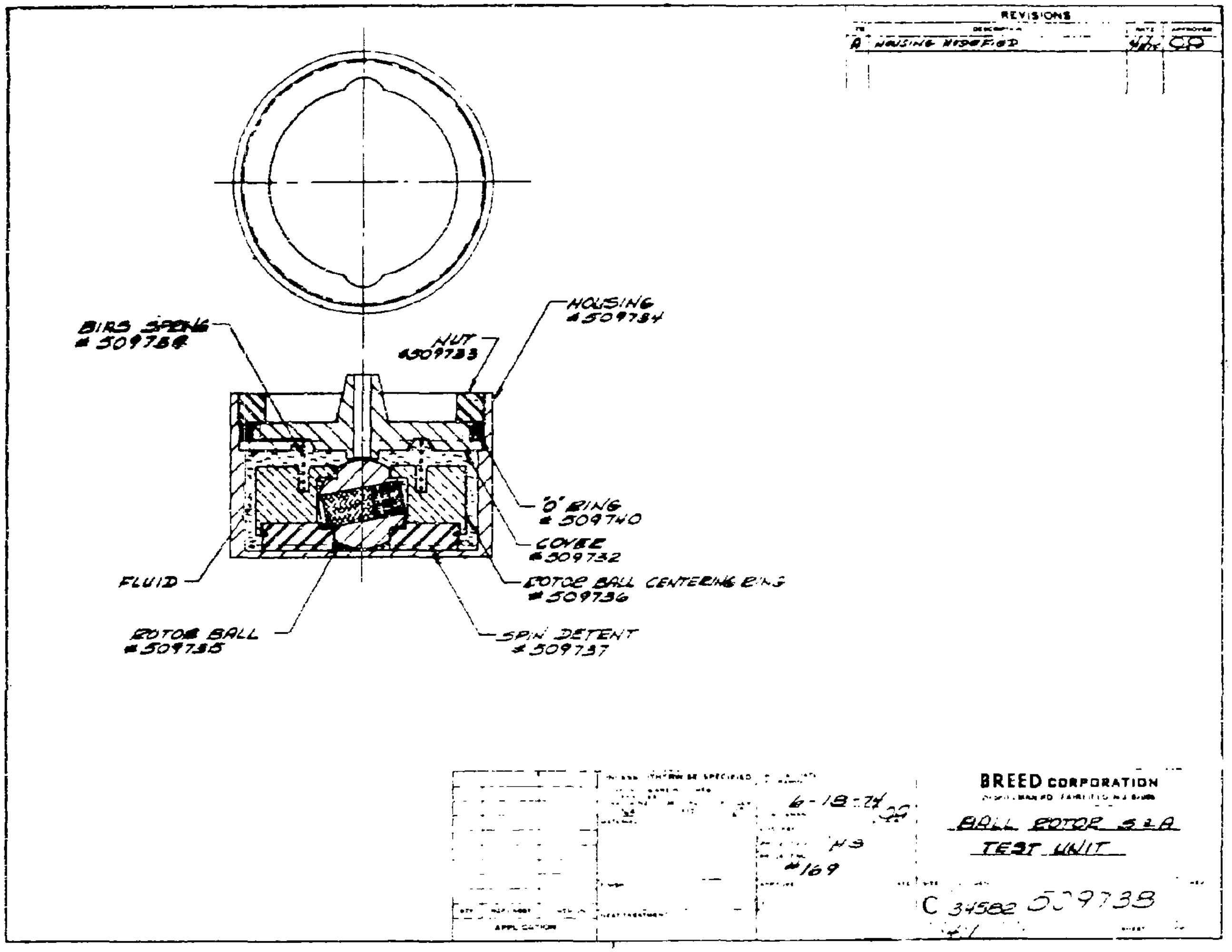

Figure 11. Ball rotor S&A test unit 509738

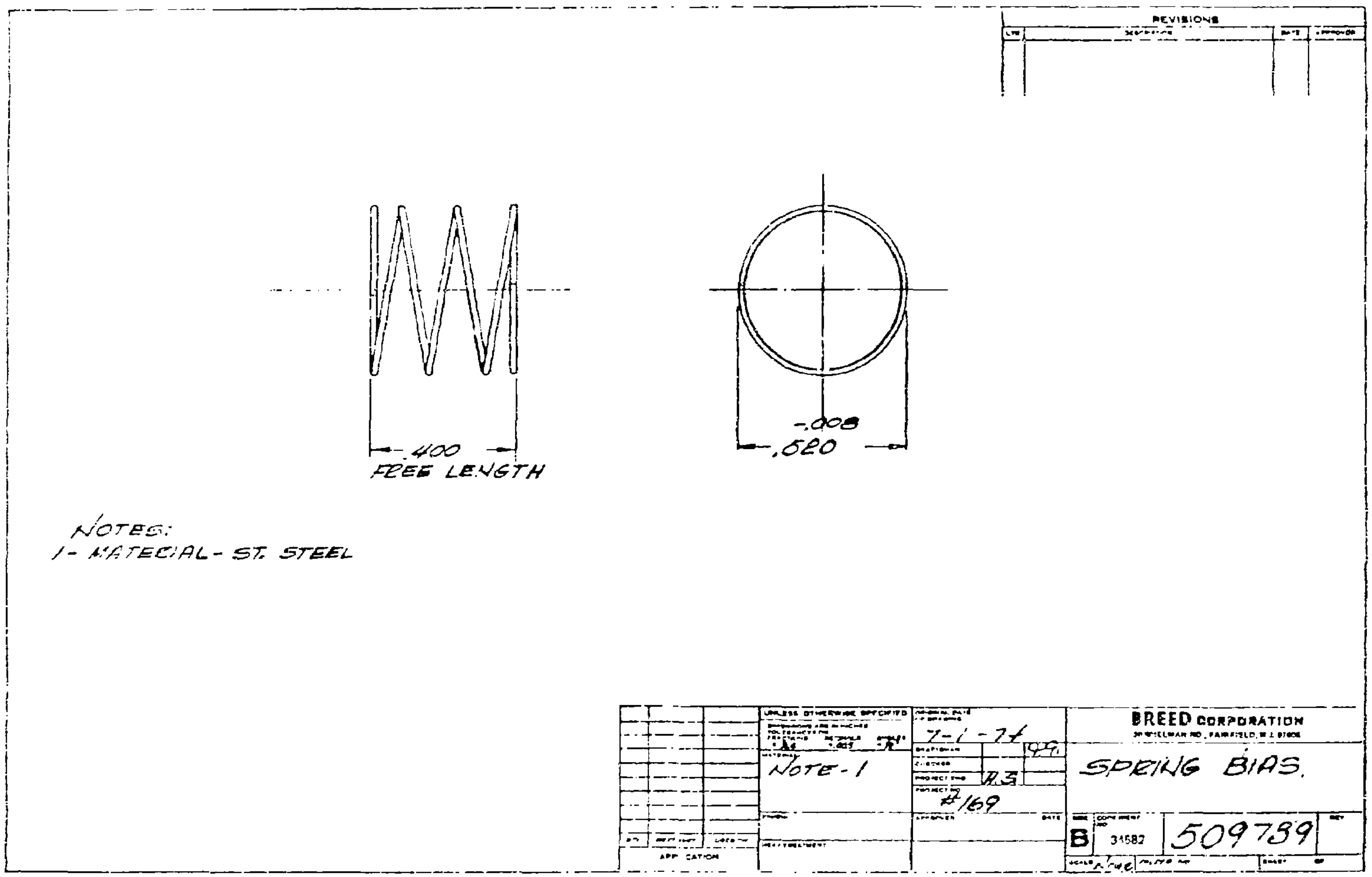

Figure 12. Bias spring used in dual safe S&A device

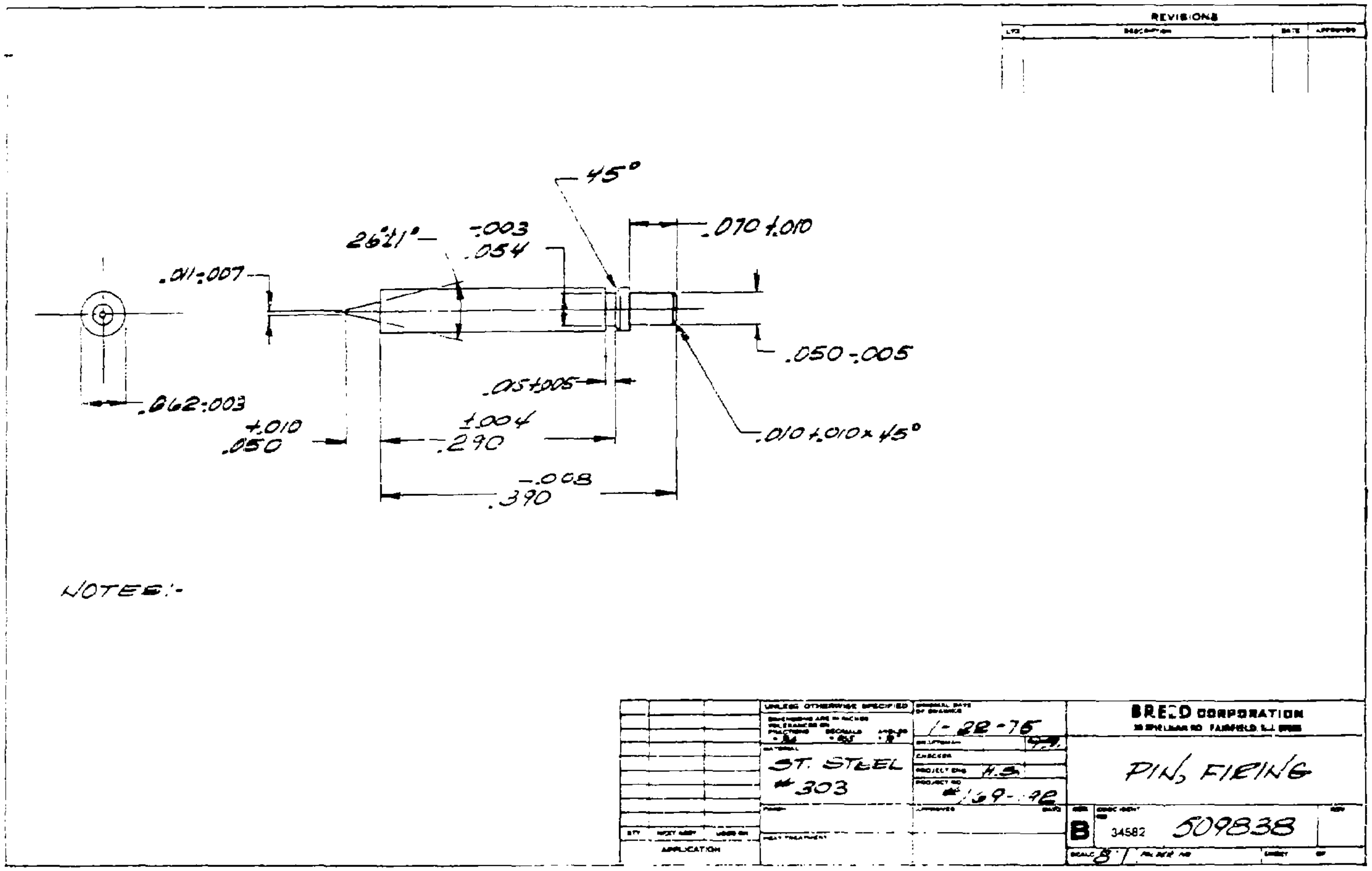

Figure 13. Firing pin used in dual safe fuze

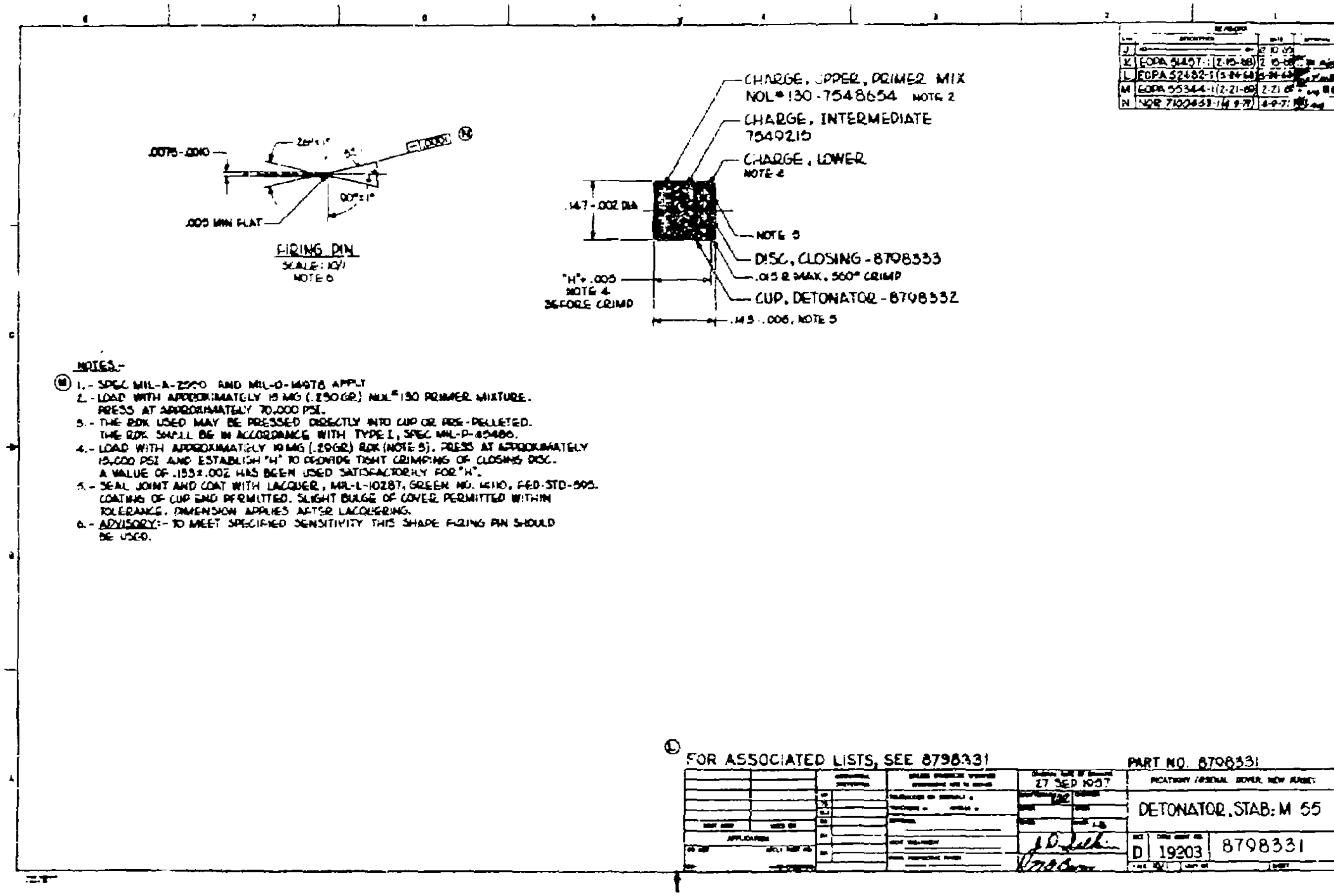

Figure 14. Detonator for ball rotor in dual safe S&A device

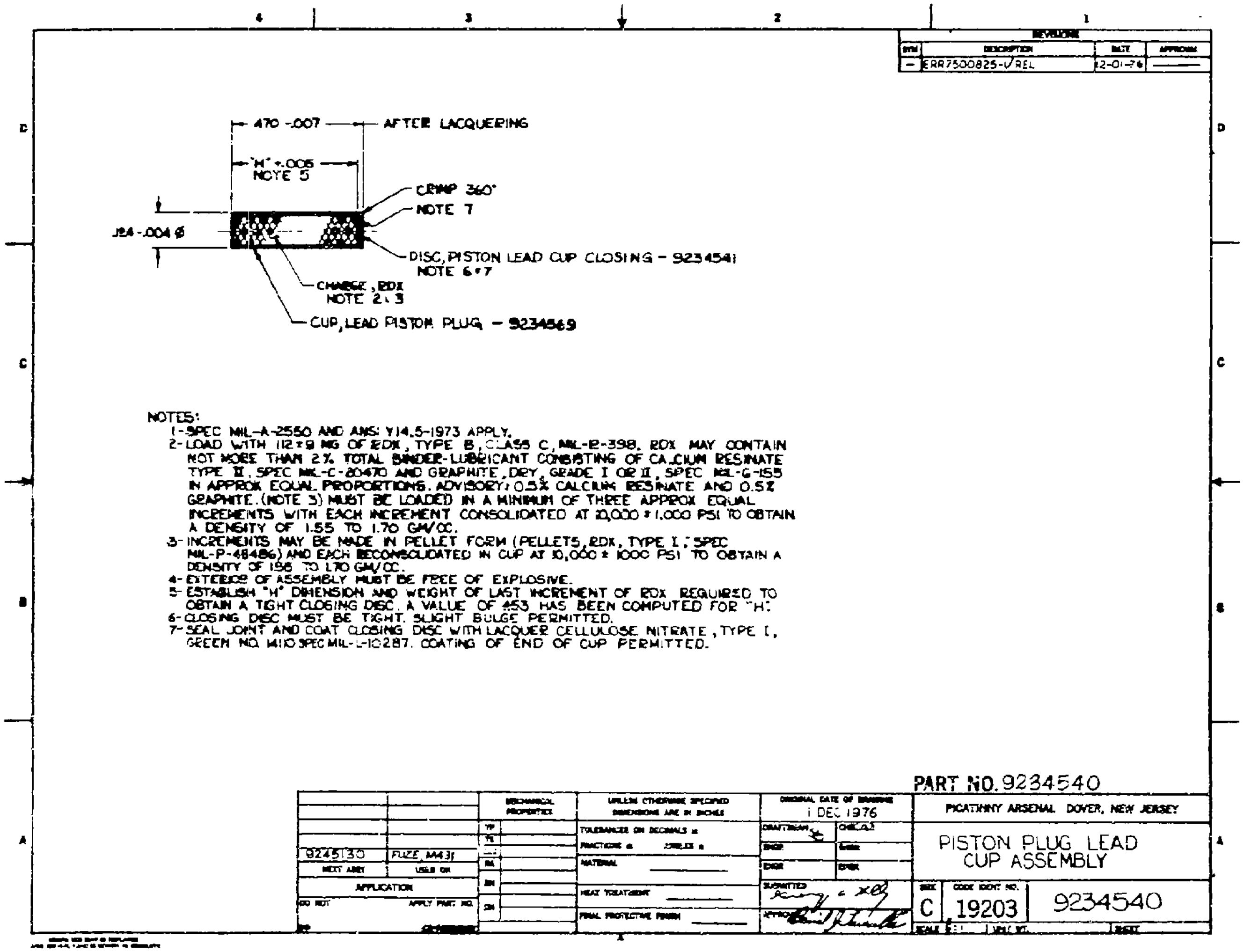

Figure 15. Lead cup assembly, relay component in dual safe fuze

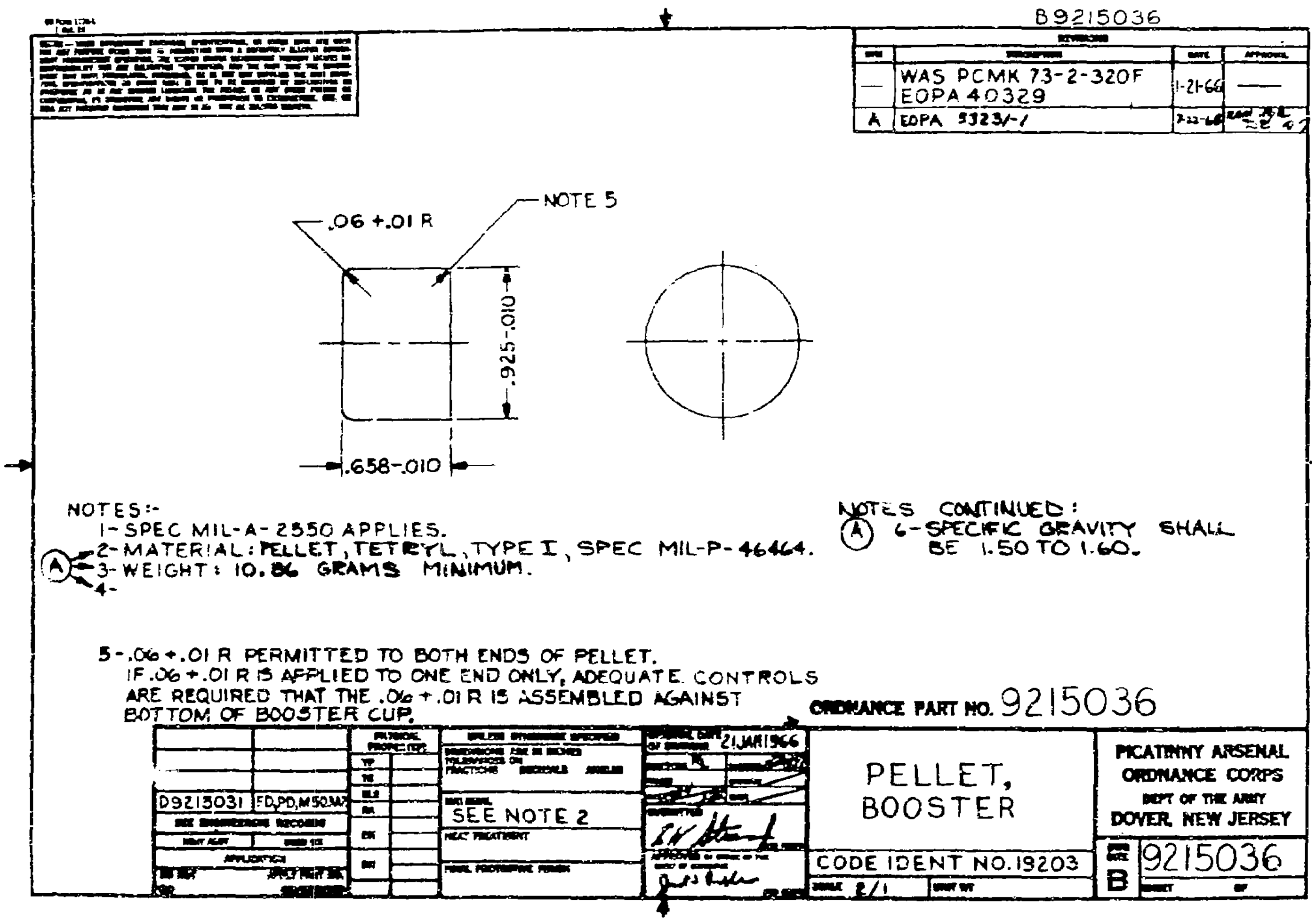

Figure 16. Booster pellet in dual safe fuze

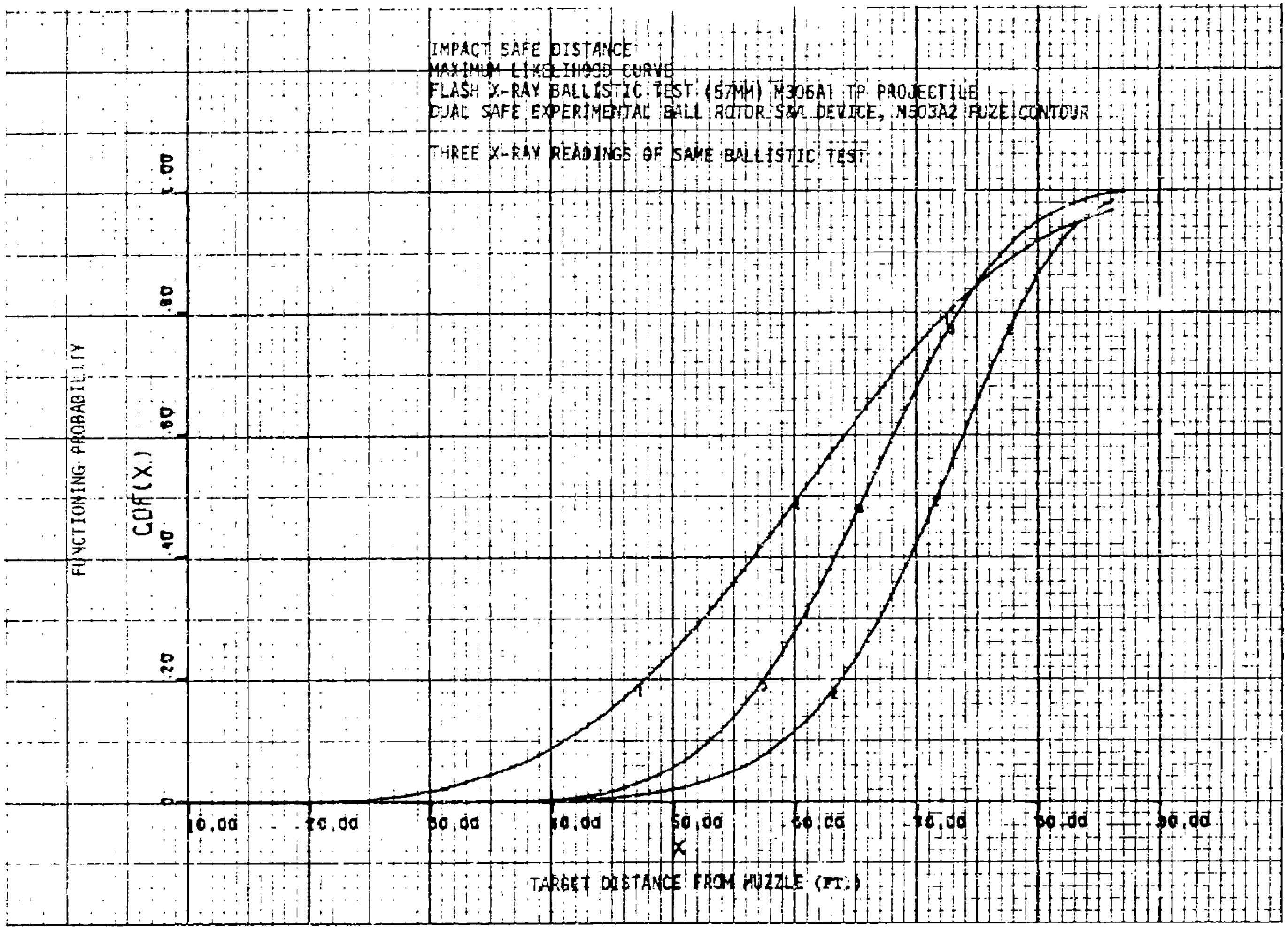

Figure 17. Plot of maximum likelihood curve, dual safe experimental ball rotor S&A device

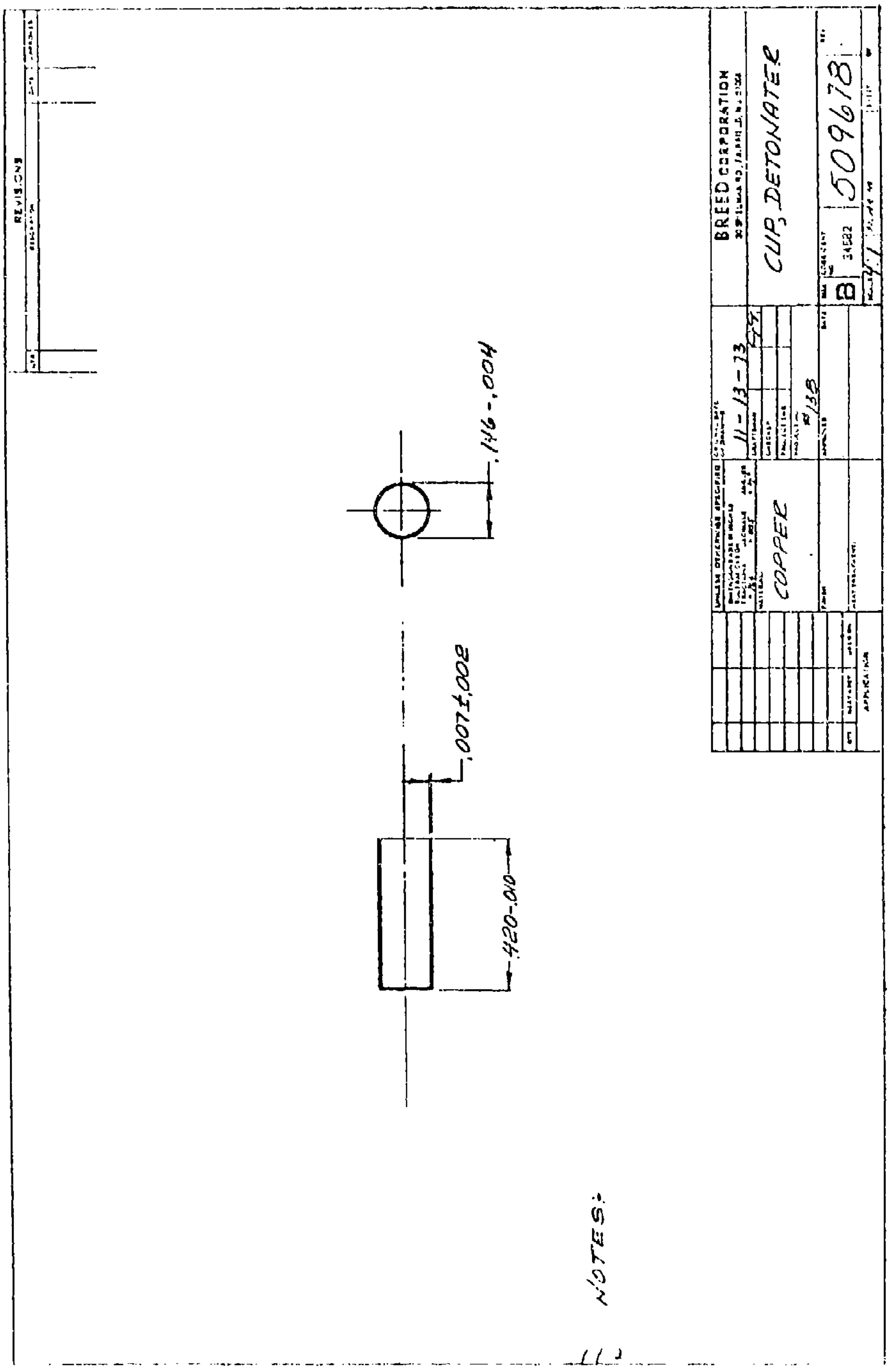

Figure 18. Detonator cup 509678

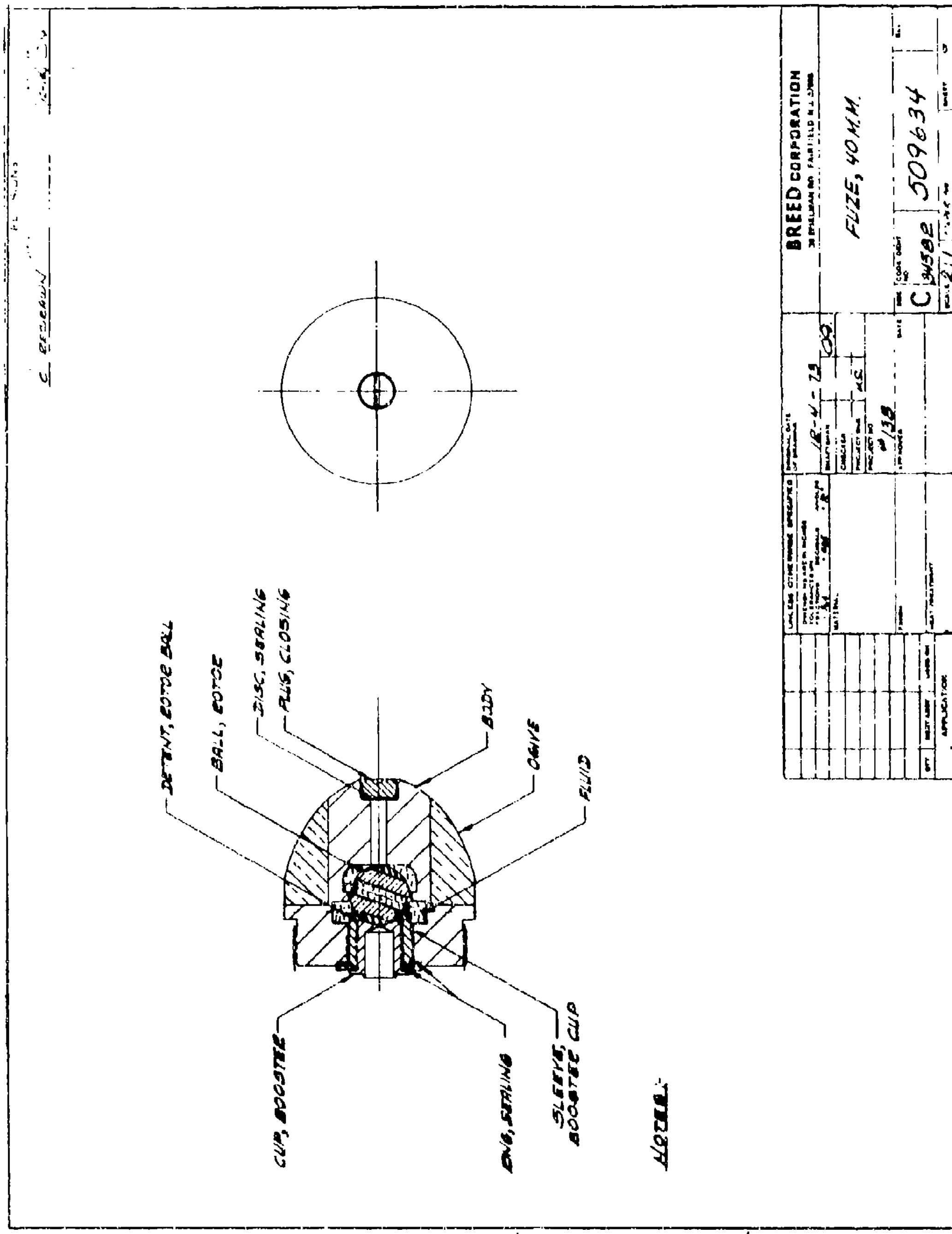

Figure 19. 40 mm fuze 509634

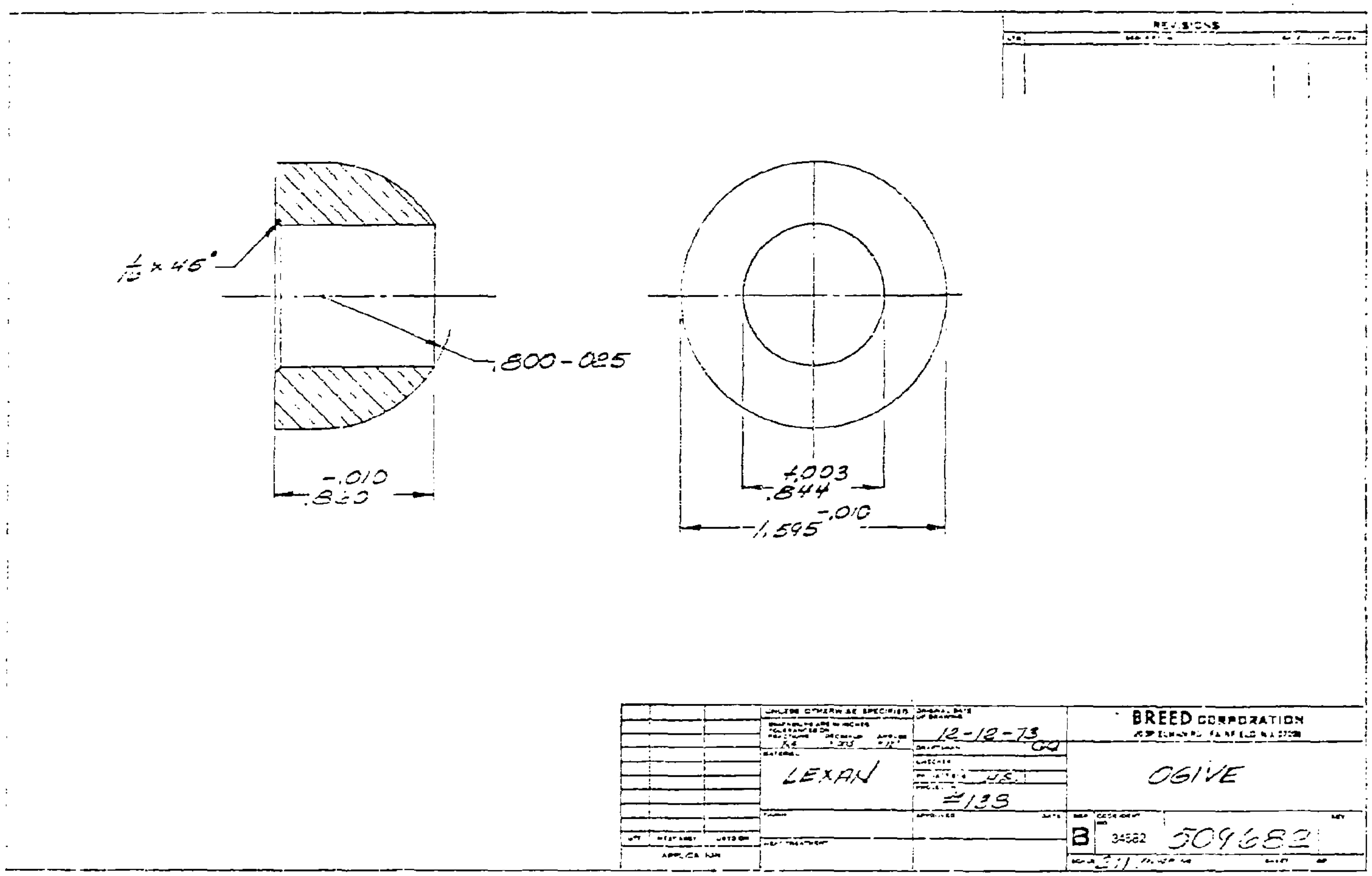

Figure 20. Ogive 509682

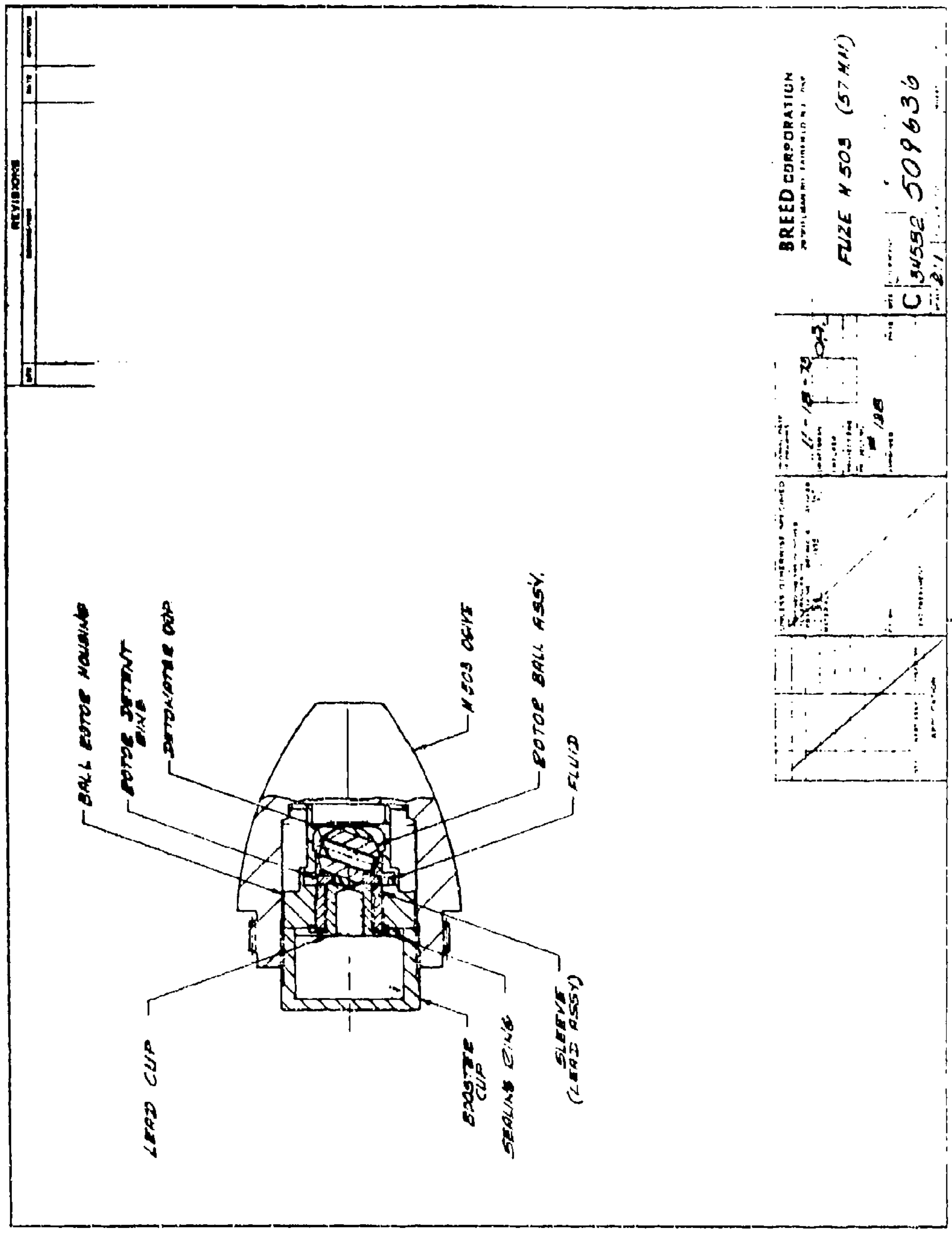

Figure 21. 57 mm fuze 509636

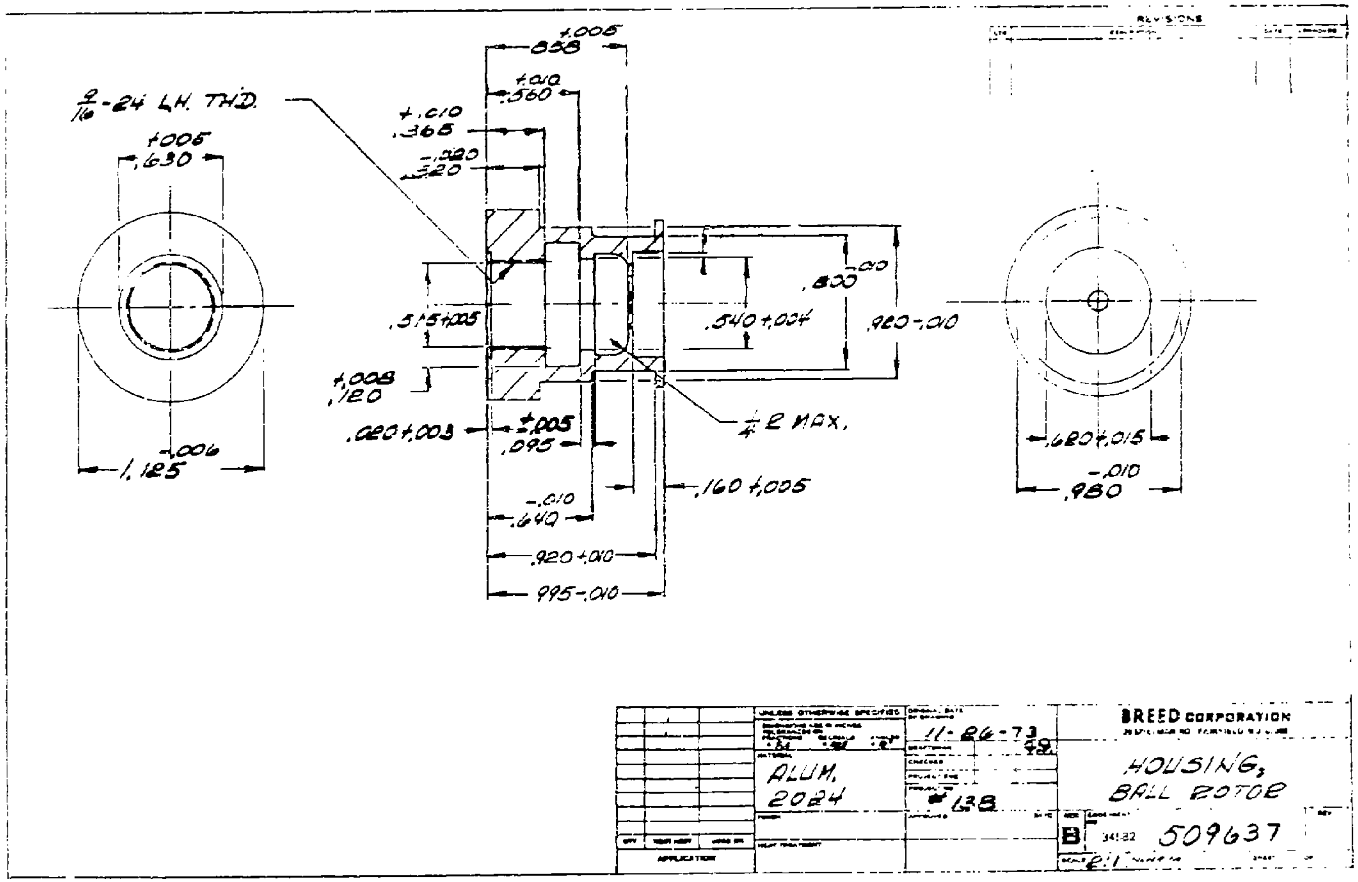

Figure 22. Ball rotor housing 509637

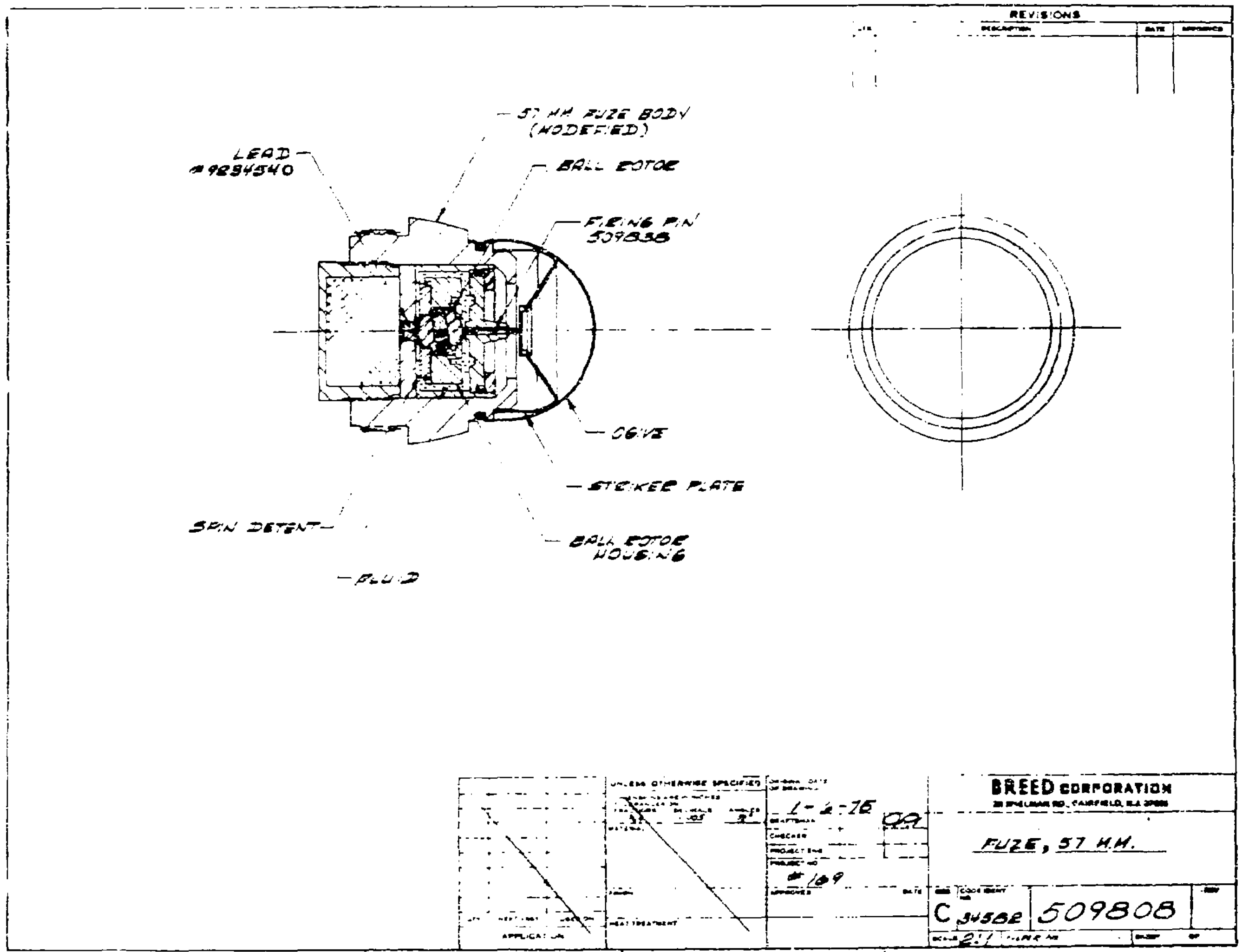

Figure 23. 57 mm fuze 509808

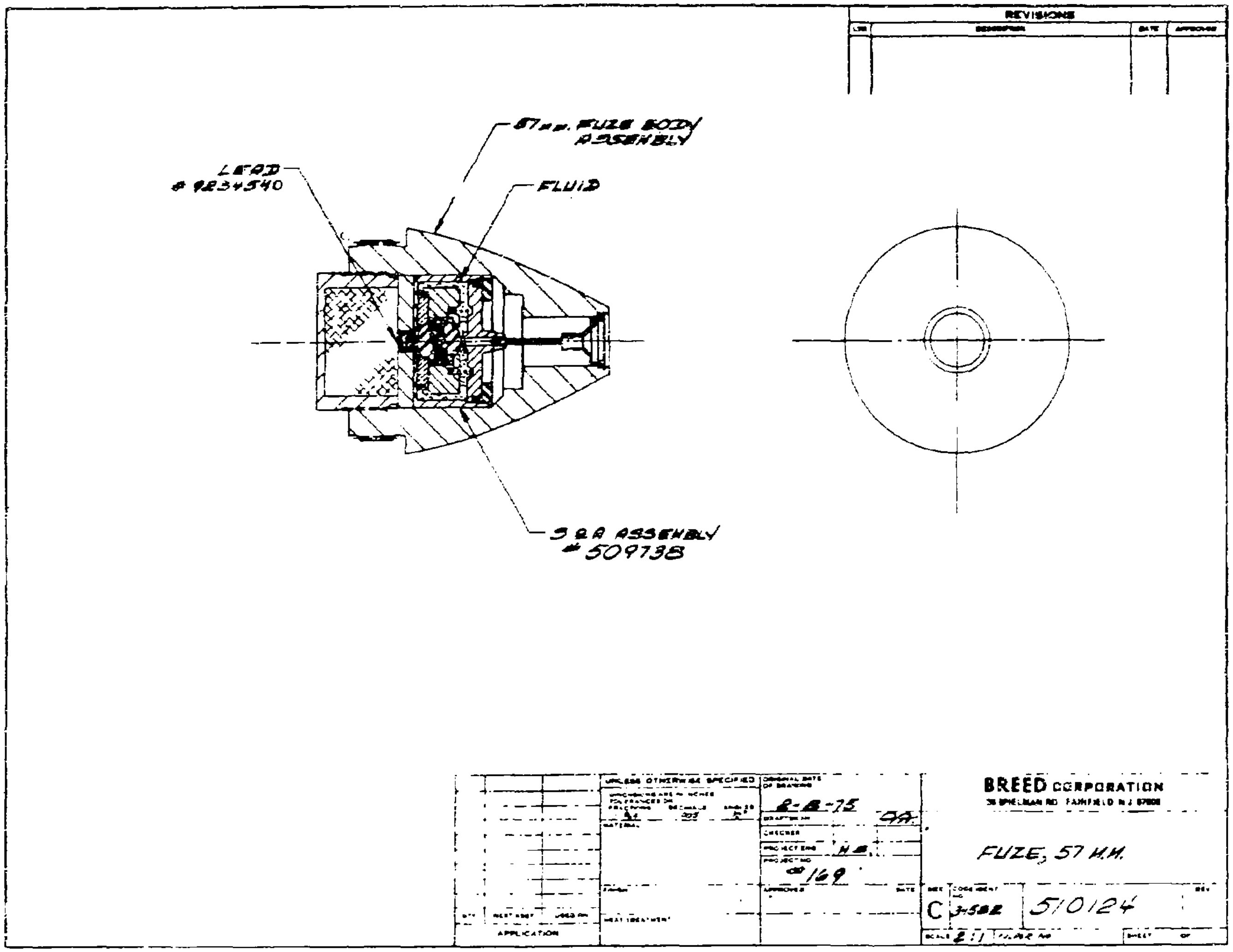

Figure 24. 57 mm fuze 510124

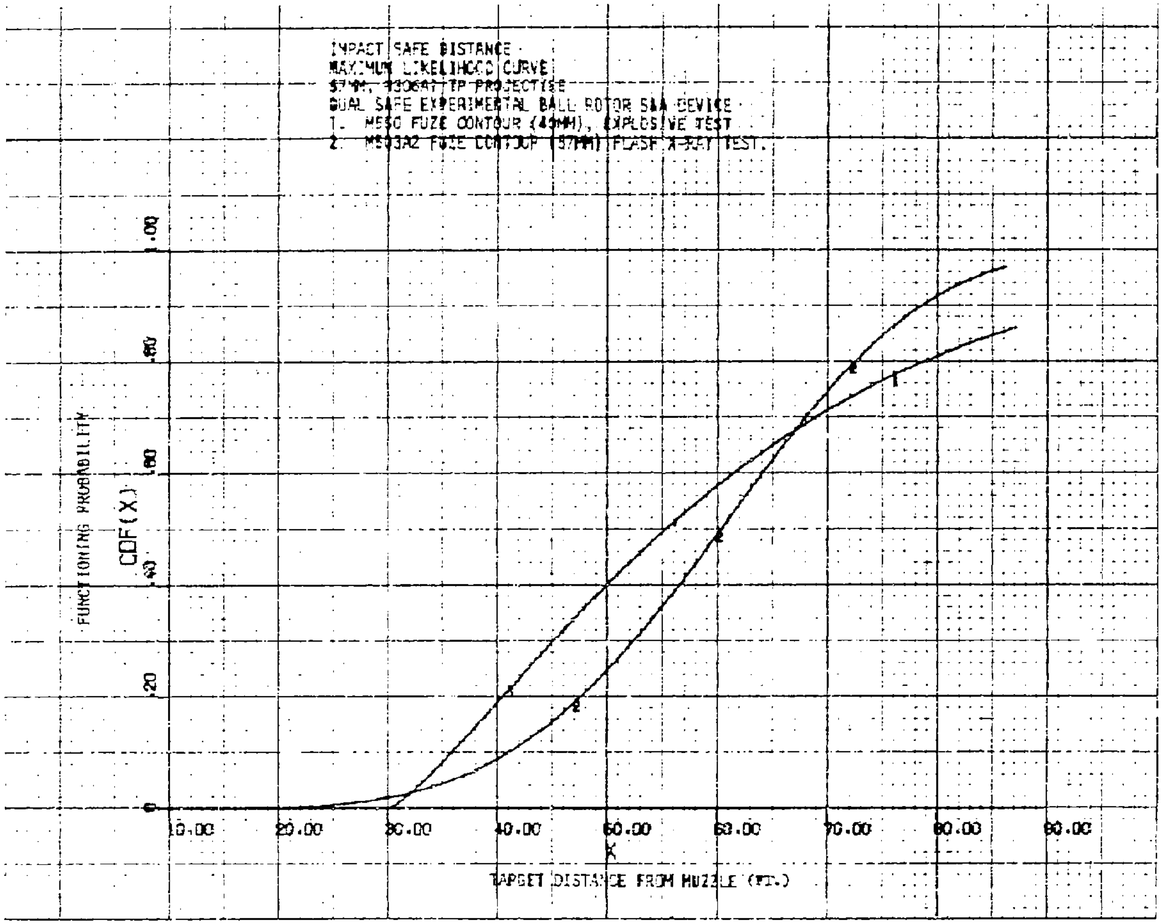

Figure 25. Plot of maximum likelihood curve, dual safe experimental ball rotor S&A device

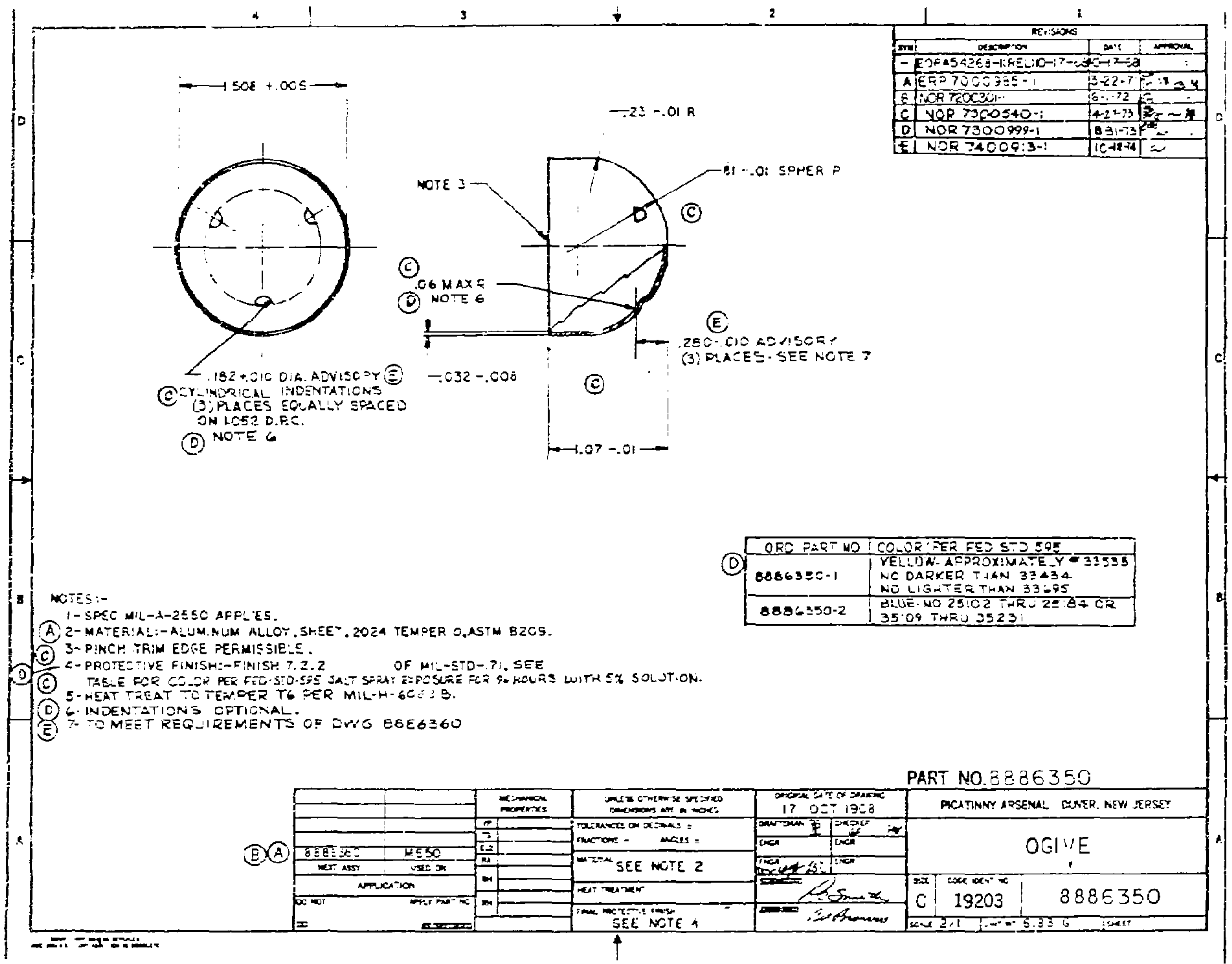

Figure 26. Ogive 8886350

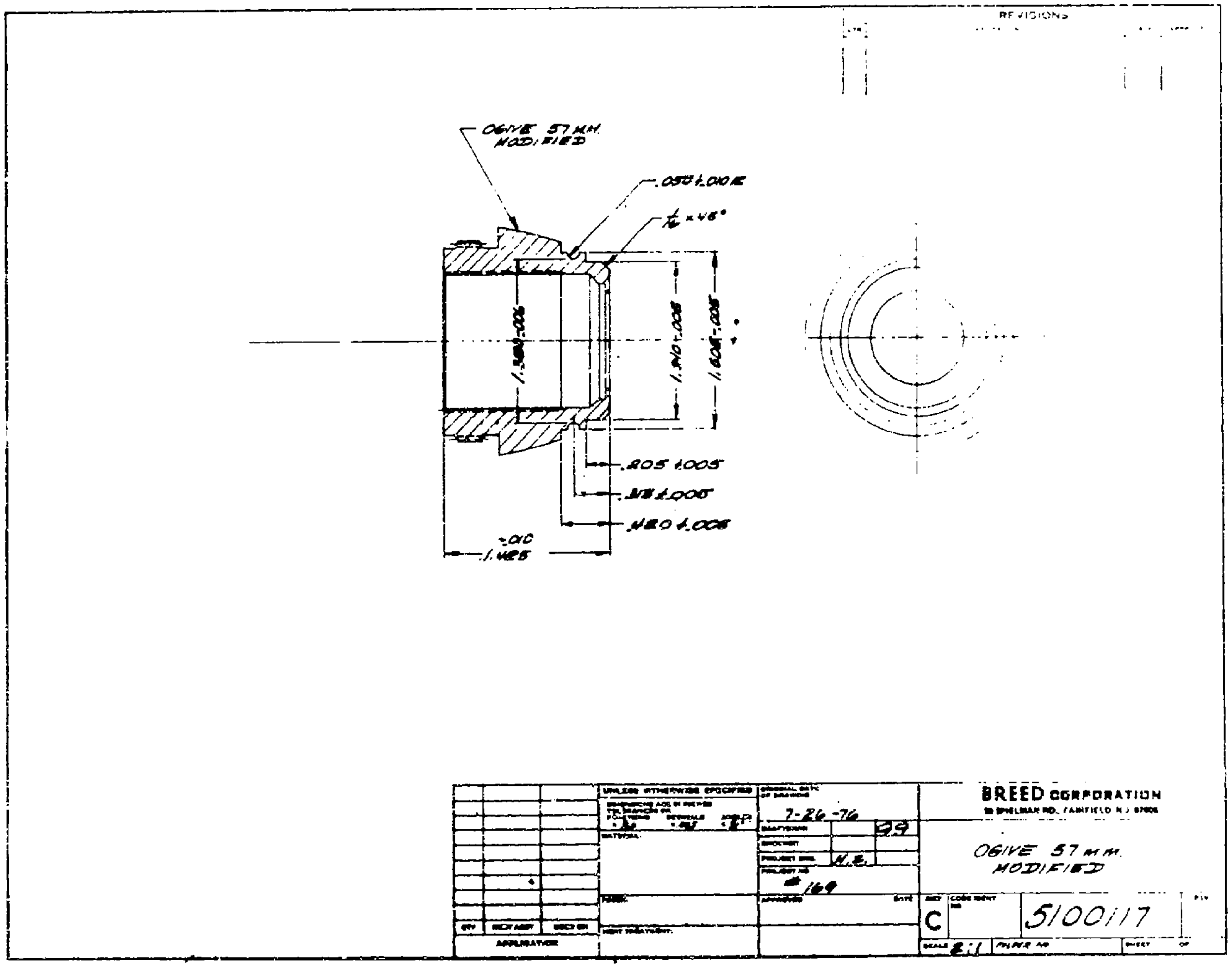

Figure 27. 57 mm modified ogive 5100117

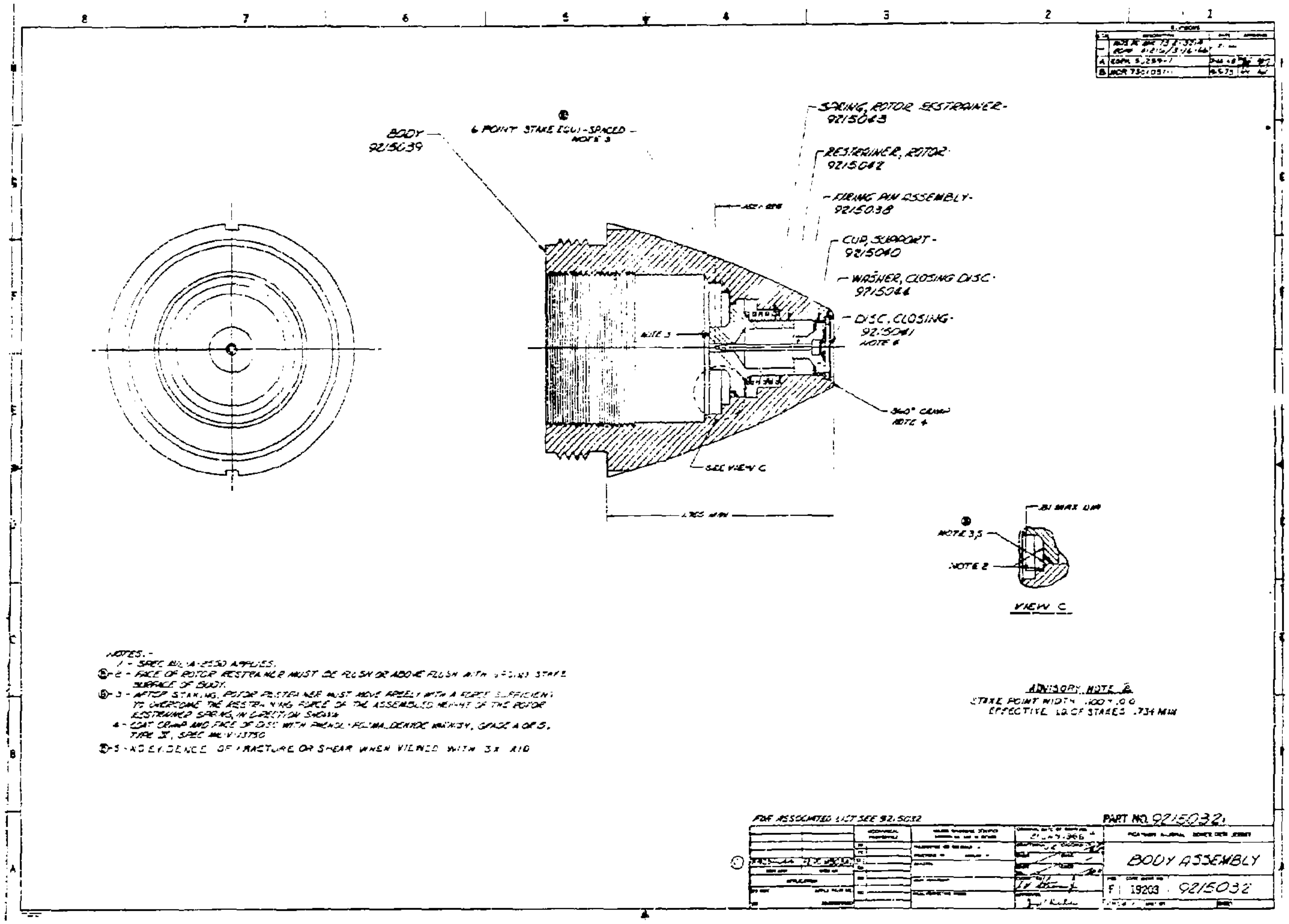

Figure 28. Body assembly, M503A2 fuze 9215032

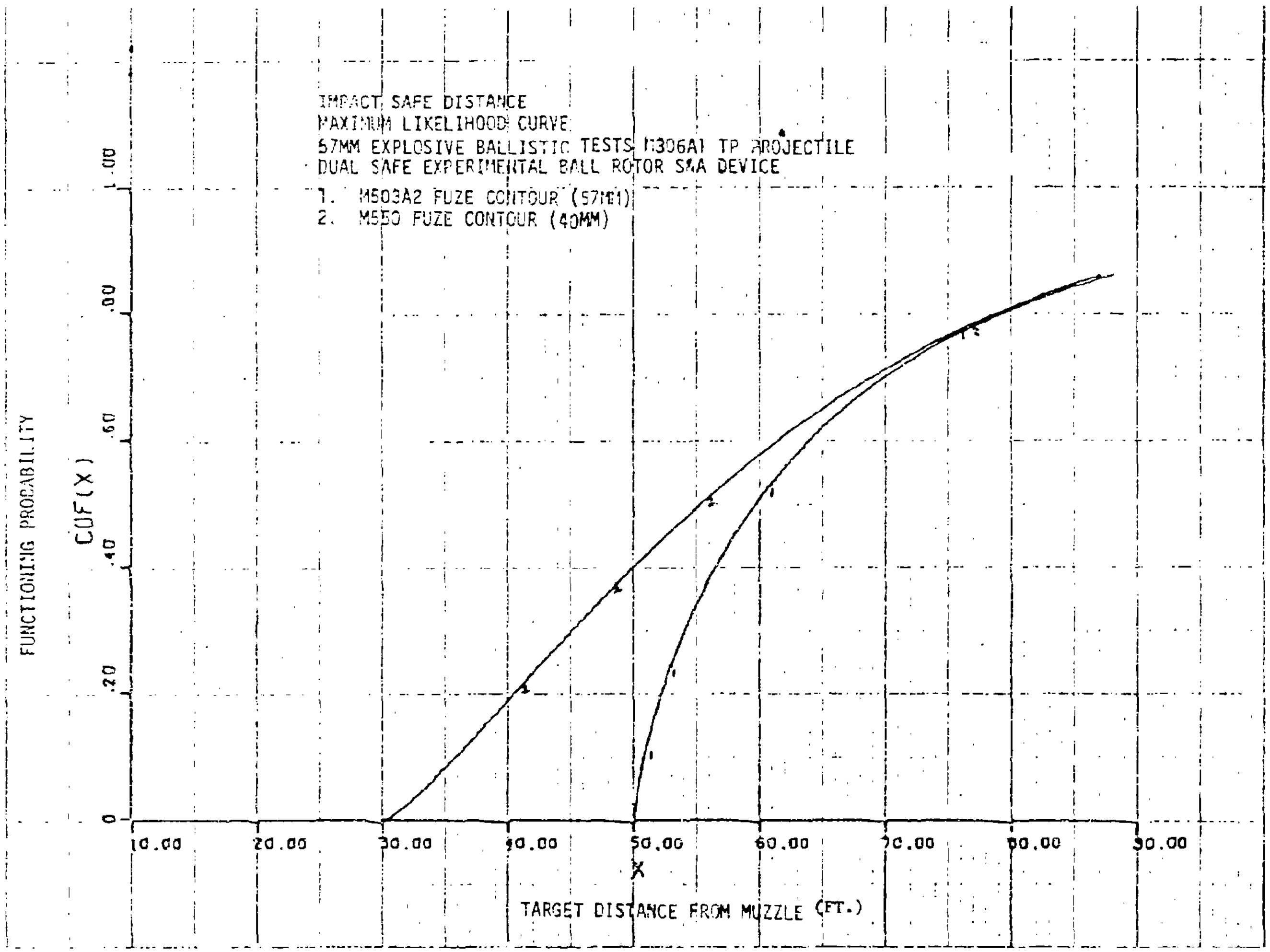

Figure 29. Plot of maximum likelihood curve, dual safe experimental ball rotor S&A device

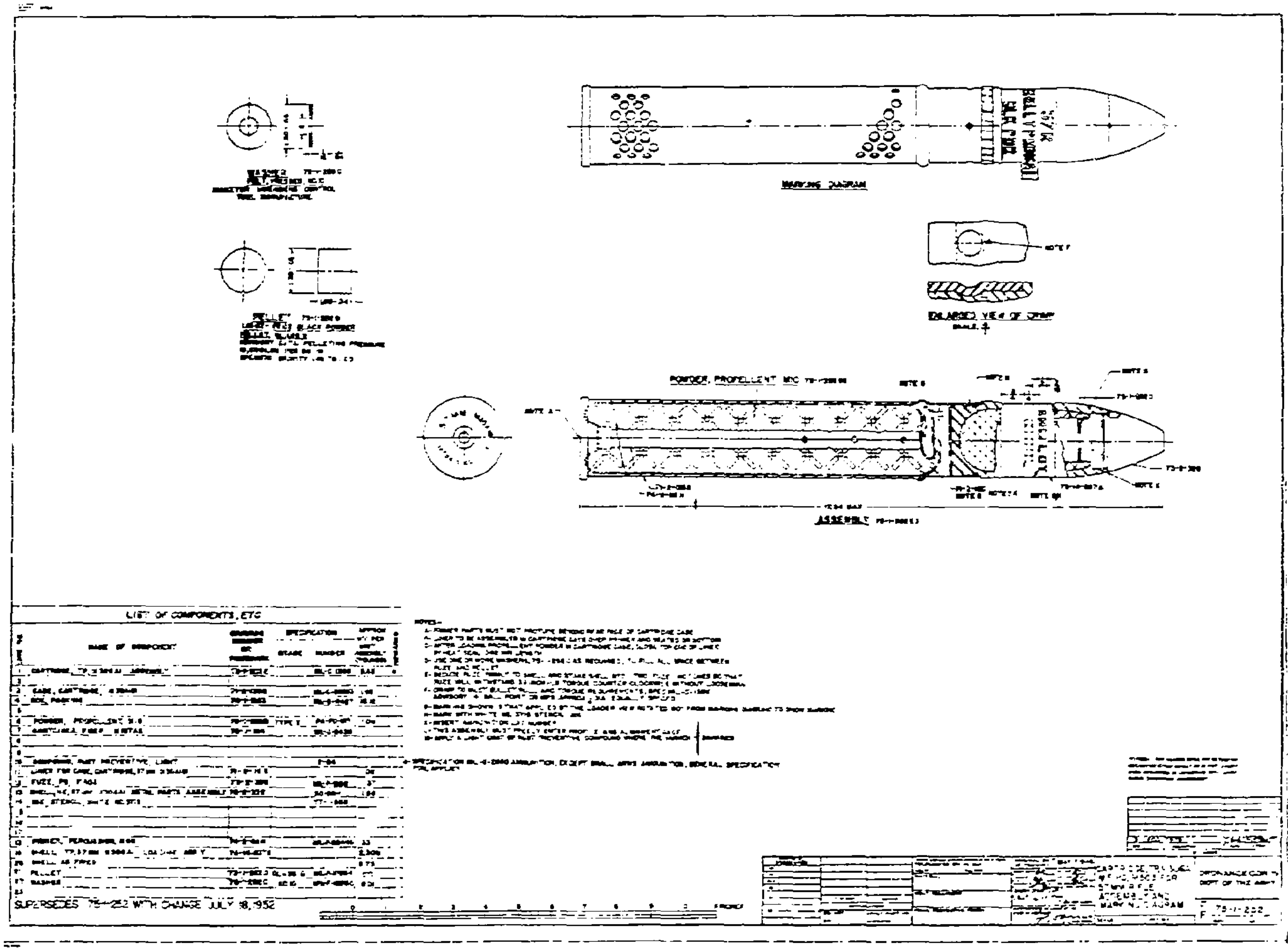

Figure 30. M306A1 TP cartridge 75-1-252

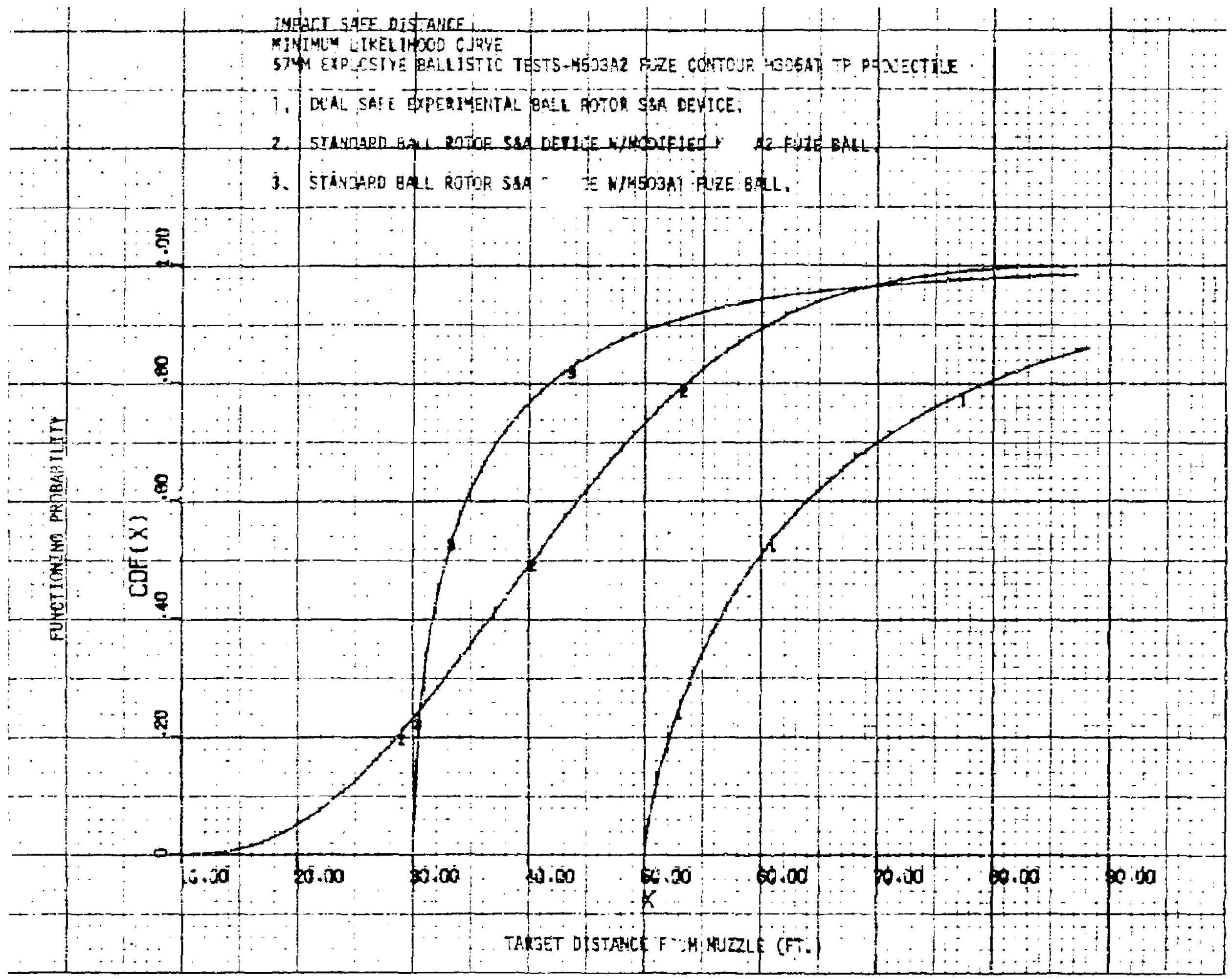

Figure 31. Plot of minimum likelihood curve, dual safe experimental ball rotor S&A device

APPENDIX A

"TIME STEP SIMULATION" PROGRAM

(Breed Corp. Rotor Ball)

```
$IPT
J7     =  1,
J8     =  3,
STIFF  =  T,
R      =  0.25E+00,
RD     =  0.7E-01,
RB     =  0.185E+00,
DL     =  0.456E+00,
DLH    =  0.456E+00,
ZN     =  0.238E+00,
ZS     =  0.238E+00,
CD     =  0.0,
CH     =  0.0,
DO     =  0.114E+01,
DB     =  0.775E+01,
DD     =  0.265E+01,
DF     =  0.2E+01,
AX     =  0.7E+02,
AY     =  0.13E+03,
AZ     =  0.0,
FC     =  0.1E+00,
EN     =  0.3E+00,
ES     =  0.6E-01,
ALIGN  =  0.11391062771249E+02,
EC     =  0.2E-01,
WSS    =  0.134E+05,
WSB    =  0.134E+05,
DRAG   =  0.2E+01,
XLR    =  0.0,
YLR    =  0.25E+00,
YDOT   =  0.13E+04,
PSTEP  =  0.17910447761194E-01,
OMEG   =  0.13541666666667E+00,
PRNT   =  0.0,   0.44776119402985E+00,   0.17910447761194E-04,
          0.55833333333333E-01,   0.0,
TL     =  0.5E-01,
TS     =  0.2E-05,
PS     =  0.25E+02,
OS     =  0.1E+02,
ELSC   =  0.29E+08,
DAMPU  =  0.0,
$END
```

CG, YT ECCENTRICITY = 0. 0. INCHES

MASS OF BALL = .356E+01 GRAMS

AVERAGE DENSITY OF BALL = .336E+01 GM/CC

EFFECTIVE MASS IN FLUID = .101E+01 GRAMS

POLAR MOMENT OF INERTIA = .73780E-06 IN-LB-SEC2
TRANSVERSE MOMENTS OF INERTIA = .540438E-06 .540438E-06 IN-LB-SEC
(IP-IT)/IP = .26730E+00 .26730E+00

NATURAL FREQUENCY OF BALL/HOUSING = 2832376. CPS

TIME	TRAV	U(1)	U(2)	ANGLE	U(3)-SP	NUTR	ECCEN	CONTR	DAMP	DFLC
.0000	.0	.31E+01	0.	70.00	.53E-01	0.	1.	340.	-.00	1.0000
.0179	21.5	-.40E+01	.21E+03	49.34	-.13E+00	301.	1.	343.	-.020	.0000
.0358	43.0	.98E+02	.16E+03	20.81	-.38E+00	41.	1.	339.	-.022	.0000
.0537	64.5	.16E+03	.14E+02	12.41	-.60E+02	342.	1.	347.	-.022	.0000
.0573	68.8	.72E-01	.13E+03	11.36	-.31E+02	202.	289.	336.	-.026	.0000

DATA OUTPUT SUMMARY

	TRAVEL	TIME	ANGLE	ECCEN	EC-ANGLE	MU
1	68.79	.057322	11.36	.0480	180.0000	.1000

```
$INPT
J7       =  1,
J8       =  3,
STIFF    =  T,
R        =  0.375E+00,
RD       =  0.79E-01,
R3       =  0.375E+00,
DL       =  0.68E+00,
DLH      =  0.68E+00,
ZN       =  0.34E+00,
ZS       =  0.34E+00,
CD       =  0.0,
CH       =  0.0,
D0       =  0.775E+01,
DB       =  0.775E+01,
DD       =  0.265E+01,
DF       =  0.0,
AX       =  0.7E+02,
AY       =  0.18E+03,
AZ       =  0.0,
FC       =  0.1E+00,
EN       =  0.3E+00,
ES       =  0.6E-01,
ALIGN    =  0.77594911708880E+01,
EC       =  0.3E-02,
WSS      =  0.104E+05,
WS2      =  0.104E+05,
DRAG     =  0.2E+01,
XLR      =  0.0,
YLR      =  0.375E+00,
YDOT     =  0.12E+04,
PSTEP    =  0.17910447761194E-01,
DFEG     =  0.19541666666667E+03,
PRNT     =  0.0,   0.44776119402985E+00,   0.17910447761194E-04,
     0.55833333333333E-01,   0.0,
TL       =  0.3E-01,
TS       =  0.2E-05,
PS       =  0.2E-03,
DS       =  0.1E+02,
ELSC     =  0.2E+03,
DAMPU    =  0.0,

   (X,Y) ECCENTRICITY =    0.         0.          INCHES

   MASS OF BALL  =     .267E+02 GRAMS

   AVERAGE DENSITY OF BALL =      .7+3E+01  GM/CC

   EFFECTIVE MASS IN FLUID =     .267E+02  GRAMS

    POLAR MOMENT OF INERTIA =        .037105E-05  IN-LB-SEC2
    TRANSVERSE MOMENTS OF INERTIA =    .352139E-05  .352139E-05 IN-LB-SEC
2

   (IP-IT)/IP =        .501235E-01    .501235E-01

   NATURAL FREQUENCY OF BALL/HOUSING =       94805. CPS


 TIME  TRAV   V1(1)   V1(2)    ANGLE  V(3)-SP NUTA  ECCEN CONTA DAMP DFLC

.0000    .0 .00E+000.         70.00  .45E-02   0.    1.   9. -.002.0000
.0179  21.5 .37E+020.         27.96  .29E+01 201.    1. 359. -.048.0000
.0313  37.6 .16E+020.          7.55  .70E+00 351.  357. 355.  .024.0000
                      DATA OUTPUT SUMMARY

            TRAVEL    TIME      ANGLE      ECCEN   EC-ANGLE     MU

      1       37.77   .031307     7.55      .0600  180.0000     .1000

                   RUN 06/30/74  AT  15.49.22.
```

APPENDIX B

"WEIGHT" PROGRAM

```
POLAR MOMENT =       1.8240

TRANSVERSE MOMENT =       6.4861

BORE DIAMETER =      2.2400

BASE DIAMETER =      2.1280

SHELL VOLUME =     20.0257

TEMPERATUREDEGF = ,    60.0000

CENTER OF GRAVITY =      2.2474

TWIST =     30.0000

PROJECTILE VELOCITY =  1170.0000

KM=      .9385

STABILITY FACTOR=     2.4491
```

OGIVE TEST 40MM

PROPERTIES OF ENTIRE SHELL

WEIGHT= 2.1254 POUNDS

CG TO REF= 2.2474 INCHES

POLAR INERTIA= 1.8240 POUND INCH SQUARE

TRANSVERSE INERTIA= 6.4861 POUND INCH SQUARE

OUTER VOLUME= 20.0257 CUBIC INCHES

```
                    OGIVE TEST 40MM
WEIGHT CALCULATION REQUESTED
PLOT REQUESTED
STABILITY CALCULATION REQUESTED, CODE NO.  1
                                             31 BODY ITEMS

                                              3 FINS

                                              2 FIN PIECES

                                              0 KNOWN ITEMS

                                              6 OGIVES

                                              1 COPIES OUTPUT REQUESTED

                                             -0 DATA CHANGES
```

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FROM COPY FURNISHED TO DDC

OGIVE TEST 40MM

INPUT DATA FOR BODY OF SHELL

NO.	IDENTIFICATION		D1	D2	LENGTH	DENSITY	REFERENCE
1	53	*	.4000	.4000	.0320	-.1000	5.6660
2	52	*	.4000	.4000	.2250	.1000	5.5060
3	53	*	.3480	.3480	.1900	-.1000	5.5410
4	51	*	.4000	1.1530	.1600	.1000	5.6660
5	50	*	1.2760	1.0890	.1600	-.1000	5.6660
6		*	1.3400	1.2760	.1600	-.1000	5.5060
7		*	1.5080	1.5080	.2600	-.1000	5.1890
8		I	1.5720	1.5740	.2600	.1000	5.1890
9	52	*	.4000	1.0890	.1600	-.1400	5.6980
10	9	*	1.4040	1.1530	.3200	.1000	5.5060
11	01	I	2.1280	2.1280	.8800	.2830	0.0000
12	02	I	2.2600	2.2600	.3700	.2830	.8800
13	03	I	2.2400	2.2400	2.5537	.2830	1.2500
14	06	*	1.8900	1.8900	1.8000	-.2830	1.1800
15	08	*	1.6536	1.6536	.6250	-.2830	4.0450
16	28	*	1.1230	1.1230	.6840	.0135	4.5880
17	29	*	.6980	.6980	.1140	-.0135	5.1580
18	30	*	.1530	.1530	.2040	.0135	5.1580
19	31	*	1.1499	1.1499	.7130	.0960	3.8750
20	32	*	.9300	.9300	.6380	-.0960	3.9500
21		*	.9250	.9258	.6580	.0540	3.9500
22	38	*	1.1500	1.1500	.7000	-.0960	4.0450
23	9	*	1.1270	1.1270	.5500	-.0960	4.7450
24	40	*	1.0000	1.0000	.1400	-.0960	5.2950
25	41	*	.8630	.8630	.0490	-.0960	5.4340
26	41	*	1.5800	1.5800	.0800	.0960	4.0450
27	42	*	1.6519	1.6519	.2600	.0960	4.1250
28	43	*	1.5800	1.5800	.1400	.0960	4.3850
29	45	*	1.5080	1.5080	.2440	.0960	5.0440
30	46	*	1.3360	1.3360	.1420	.0960	5.2710
31	47	*	1.3360	1.1950	.0710	.0960	5.4130

INPUT DATA FOR FINS

3-FINS

NO.	IDENTIFICATION		R1	R2	LENGTH	DENSITY	REFERENCE	THICKNESS
1	55	*	.6700	.6700	.2350	-.1000	5.2710	.2700
2	54	*	.7020	.7020	.2350	.1000	5.2710	.2700

INPUT DATA FOR OGIVAL ITEMS

NO.	IDENTIFICATION		A	B	LENGTH	DENSITY	REFERENCE	RADIUS
1	04	I	.4400	3.3800	.8663	.2830	3.8000	4.5000
2	44	I	1.8700	6.3200	.5190	.0960	4.6630	7.5000
3	65	I	.1900	0.0000	.6200	.1000	5.4490	.8100
4	57	*	.1900	0.0000	.5880	-.1000	5.4490	.7780
5	07	*	0.0000	4.1550	1.0700	-.2830	2.9800	5.1000
6	05	*	-.9300	0.0000	.9300	-.2830	.2500	.9300

OGIVE TEST 40MM

PROPERTIES OF BODY ITEMS

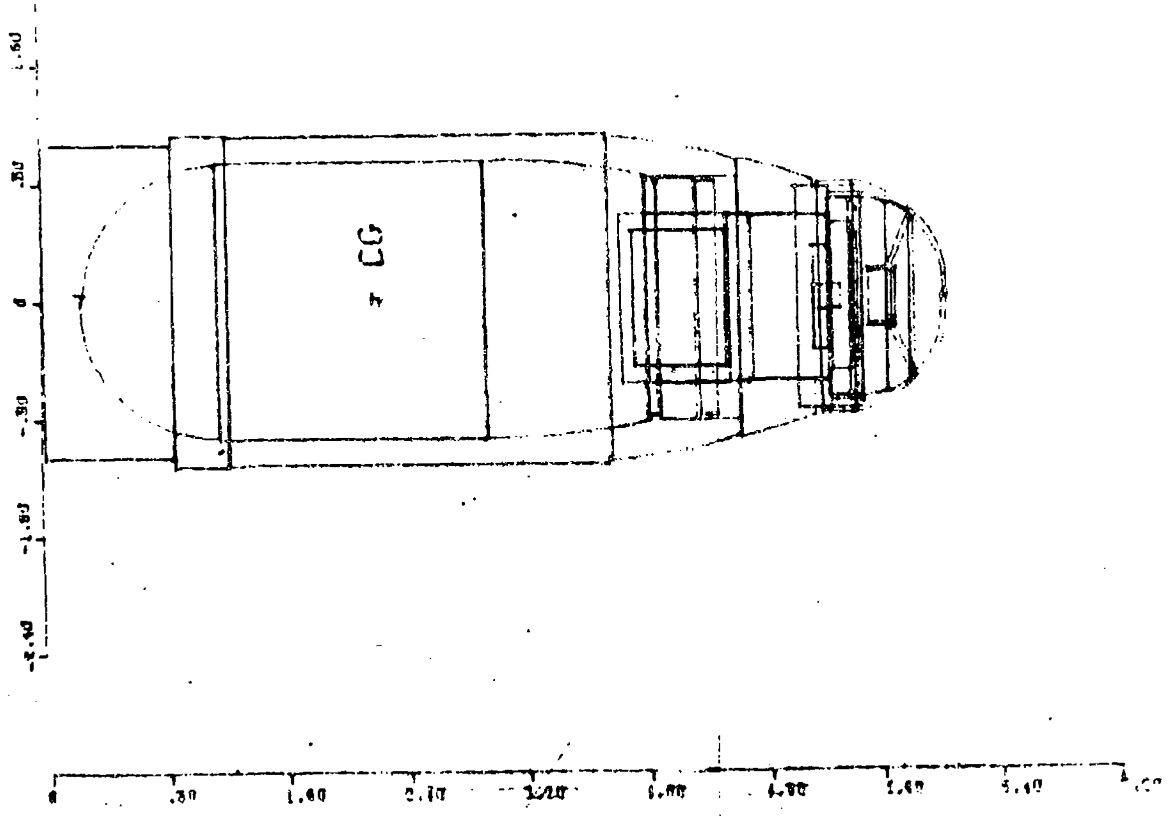
NO.	IDENTIFICATION		WEIGHT	POLAR I	TRANSVERSE I	CG TO REF	VOLUME
1	53	*	-.0004	-.0000	-.0000	5.6820	.0040
2	52	*	.0028	.0001	.0000	5.6185	.0283
3	53	*	-.0018	-.0000	-.0000	5.6360	.0181
4	51	*	.0082	.0008	.0000	5.7700	.0817
5	50	*	-.0176	-.0031	-.0000	5.7418	.1761
6		*	-.0215	-.0046	-.0000	5.5847	.2150
7		*	-.0464	-.0132	-.0003	5.3190	.4644
8		1	.0505	.0156	.0003	5.3191	.5053
9	52	*	-.0075	-.0007	-.0000	5.8010	.0746
10	8	*	.0412	.0086	.0003	5.6556	.4121
11	01	1	.8857	.5014	.0572	.4400	3.1298
12	02	1	.4200	.2682	.0048	1.0650	1.4843
13	03	1	2.8480	1.7863	1.5477	2.5269	10.0637
14	06	*	-1.4291	-.6381	-.3859	2.0800	5.0499
15	08	*	-.3799	-.1298	-.0124	4.3575	1.3422
16	28	*	.0091	.0014	.0004	4.9300	.6775
17	29	*	-.0005	-.0000	-.0000	5.2150	.0436
18	30	*	.0001	.0000	.0000	5.2600	.0038
19	31	*	.0711	.0117	.0030	4.2315	.7405
20	32	*	-.0416	-.0045	-.0014	4.2690	.4334
21		*	.0239	.0026	.0009	4.2790	.4422
22	38	*	-.0698	-.0115	-.0029	4.3950	.7271
23	9	*	-.0527	-.0084	-.0013	5.0200	.5487
24	40	*	-.0106	-.0013	-.0000	5.3650	.1100
25	41	*	-.0023	-.0003	-.0000	5.4585	.0287
26	41	*	.0151	.0047	.0000	4.0850	.1569
27	42	*	.0535	.0182	.0003	4.2550	.5572
28	43	*	.0264	.0062	.0000	4.4550	.2745
29	45	*	.0419	.0119	.0002	5.1660	.4358
30	46	*	.0191	.0043	.0000	5.3420	.1991
31	47	*	.0086	.0017	.0000	5.4472	.0894

PROPERTIES OF FIN ITEMS

NO.	IDENTIFICATION		WEIGHT	POLAR I	TRANSVERSE I	CG TO REF	VOLUME
1	55	*	-.0128	-.0019	-.0001	5.3865	.1275
2	54	*	.0134	.0022	.0001	5.3865	.1336

PROPERTIES OF OGIVAL ITEMS

NO.	IDENTIFICATION		WEIGHT	POLAR I	TRANSVERSE I	CG TO REF	VOLUME
1	04	1	.8144	.4346	.0500	4.2092	2.8779
2	44	1	.1187	.0455	.0026	4.9073	1.2363
3	65	1	.0729	.0168	.0016	5.6733	.7285
4	57	*	-.0632	-.0134	-.0013	5.6615	.6321
5	07	*	-.7842	-.3250	-.0733	3.4930	2.7712
6	05	*	-.4767	-.1649	-.0245	.8313	1.6844



OGIVE TEST 40MM

WEIGHT(LBS.)= 2.1254

CG(IN.)= 2.2474

POLAR I (LB.IN.SQ.)= 1.9240

TRANS I (LB.IN.SQ.)= 6.8861

STABILITY FACTOR= 2.45

32

17

```
POLAR MOMENT =       1.8307
TRANSVERSE MOMENT =       6.9478
BORE DIAMETER =      2.2400
BASE DIAMETER =      2.1280
SHELL VOLUME =     20.2274
TEMPERATUREDEGF = ,    60.0000
CENTER OF GRAVITY =       2.3046
TWIST =     30.0000
PROJECTILE VELOCITY =  1170.0000
KM=      .9334

STABILITY FACTOR=     2.3158
```

OGIVE TEST 57MM

PROPERTIES OF ENTIRE SHELL

WEIGHT= 2.1577 POUNDS

CG TO REF= 2.3046 INCHES

POLAR INERTIA= 1.8307 POUND INCH SQUARE

TRANSVERSE INERTIA= 6.9478 POUND INCH SQUARE

OUTER VOLUME= 20.2274 CUBIC INCHES

```
                  OGIVE TEST 57MM
WEIGHT CALCULATION REQUESTED
PLOT REQUESTED
STABILITY CALCULATION REQUESTED, CODE NO.  1
                                            34 BODY ITEMS

                                             0 FINS

                                             0 FIN PIECES

                                             0 KNOWN ITEMS

                                             4 OGIVES

                                             1 COPIES OUTPUT REQUESTED

                                            -0 DATA CHANGES
```

OGIVE TEST 57MM

INPUT DATA FOR BODY OF SHELL

.O.	IDENTIFICATION		D1	D2	LENGTH	DENSITY	REFERENCE
1	09	*	1.1500	1.1500	.7000	-.0960	4.0450
2	10	*	1.1270	1.1270	.5500	-.0930	4.7450
3	11	*	1.0000	1.0000	.1400	-.0960	5.2950
4	12	*	.8630	.8630	.0650	-.0960	5.4340
5	13	*	.7500	.7500	.2100	-.0960	5.4990
6	14	*	.5900	.5900	.1750	-.0960	5.7090
7	5	*	.4200	.4200	.3100	-.0960	5.8840
8	16	*	.4830	.4830	.0450	-.0960	6.2940
9	17	*	.5030	.5030	.0400	-.0960	6.3390
10	8	1	.4800	.4800	.0100	.0980	6.3390
11	9	*	.4800	.4800	.0320	.3080	6.3070
12	0	*	.4100	.4100	.0320	-.3080	6.3070
13	21	*	.4190	.4190	.0860	.3060	6.2210
14	22	*	.4070	.4070	.0810	-.3060	6.2260
15	23	*	.1240	.1240	.0710	.2830	6.1500
16	24	*	.0150	.0480	.7560	.2830	5.3940
17	24	*	.1600	.3000	.1700	.1020	5.9710
18	25	*	.0580	.0500	.1550	-.1020	5.9710
19	26	*	.4050	.4050	.0800	.1020	6.1410
20		*	.1250	.1250	.0950	-.1020	6.1410
21	28	*	1.1230	1.1230	.6840	.0135	4.5880
22	29	*	.6980	.6980	.1140	-.0135	5.1580
23	30	*	.1530	.1530	.2040	.0135	5.1580
24	31	*	1.1499	1.1499	.7130	.0960	3.8750
25	32	*	.9300	.9300	.6380	-.0960	3.9500
26		*	.9250	.9250	.6580	.0540	3.9500
27	34	*	1.5800	1.5800	.0800	.0960	4.0450
28	35	*	1.6519	1.6519	.2600	.0960	4.1250
29	36	*	1.5800	1.5800	.1400	.0960	4.3850
30	01	1	2.1280	2.1280	.8800	.2830	0.0000
31	02	1	2.2600	2.2600	.3700	.2830	.8600
32	03	1	2.2400	2.2400	2.5500	.2830	1.2500
33	06	*	1.8900	1.8900	1.8000	-.2830	1.1300
34	08	*	1.6536	1.6536	.6250	-.2830	4.0450

INPUT DATA FOR OGIVAL ITEMS

NO.	IDENTIFICATION		A	B	LENGTH	DENSITY	REFERENCE	RADIUS
1	04	1	.4400	3.3800	.8663	.2830	3.8000	4.5000
2	5	*	-.9300	0.0000	.9300	-.2830	.2500	.9300
3	07	*	0.0000	4.1550	1.0700	-.2830	2.9800	5.1000
4	07	1	1.8700	6.2900	1.7800	.0960	4.6200	7.5000

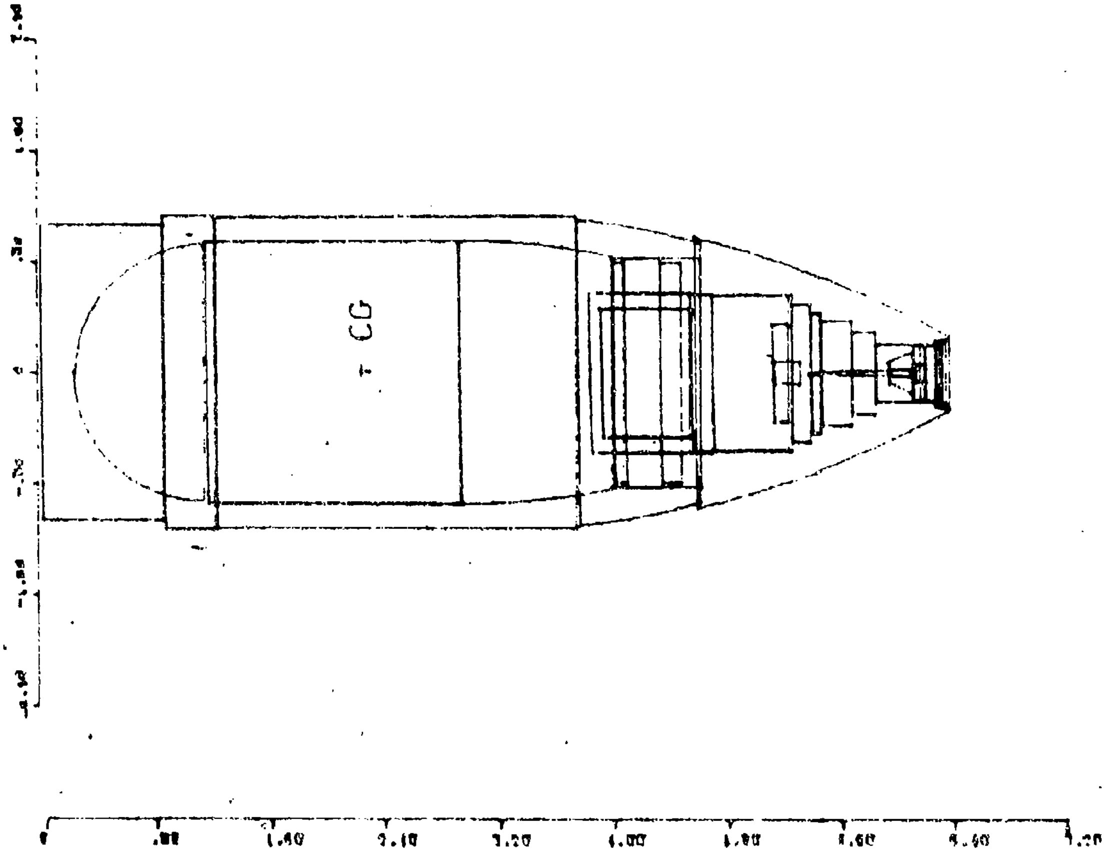
OGIVE TEST 57MM

PROPERTIES OF BODY ITEMS

NO.	IDENTIFICATION		WEIGHT	POLAR I	TRANSVERSE I	CG TO REF	VOLUME
1	09	*	-.0698	-.0115	-.0029	4.3950	.7271
2	10	*	-.0510	-.0081	-.0013	5.0200	.5487
3	11	*	-.0106	-.0013	-.0000	5.3650	.1100
4	12	*	-.0037	-.0003	-.0000	5.4665	.0380
5	13	*	-.0089	-.0006	-.0000	5.6040	.0928
6	14	*	-.0046	-.0002	-.0000	5.7965	.0478
7	5	*	-.0041	-.0001	-.0000	6.0390	.0429
8	16	*	-.0008	-.0000	-.0000	6.3165	.0082
9	17	*	-.0008	-.0000	-.0000	6.3590	.0079
10	8	1	.0002	.0000	.0000	6.3440	.0018
11	9	*	.0018	.0001	.0000	6.3230	.0058
12	0	*	-.0013	-.0000	-.0000	6.3230	.0042
13	21	*	.0036	.0001	.0000	6.2640	.0119
14	22	*	-.0032	-.0001	-.0000	6.2665	.0105
15	23	*	.0002	.0000	.0000	6.1855	.0009
16	24	*	.0002	.0000	.0000	5.8929	.0006
17	24	*	.0007	.0000	.0000	6.0727	.0073
18	25	*	-.0000	-.0000	-.0000	6.0485	.0003
19	26	*	.0011	.0000	.0000	6.1810	.0103
20		*	-.0001	-.0000	-.0000	6.1885	.0012
21	28	*	.0091	.0014	.0004	4.9300	.6775
22	29	*	-.0006	-.0000	-.0000	5.2150	.0436
23	30	*	.0001	.0000	.0000	5.2600	.0038
24	31	*	.0711	.0117	.0030	4.2315	.7405
25	32	*	-.0416	-.0045	-.0014	4.2690	.4334
26		*	.0239	.0026	.0009	4.2790	.4422
27	34	*	.0151	.0047	.0000	4.0850	.1569
28	35	*	.0535	.0182	.0003	4.2550	.5572
29	36	*	.0264	.0082	.0000	4.4550	.2745
30	01	1	.8857	.5014	.0572	.4400	3.1298
31	02	1	.4200	.2682	.0048	1.0650	1.4843
32	03	1	2.8439	1.7837	1.5410	2.5250	10.0491
33	06	*	-1.4291	-.6381	-.3659	2.0800	5.0499
34	08	*	-.3799	-.1298	-.0124	4.3575	1.3422

PROPERTIES OF OGIVAL ITEMS

NO.	IDENTIFICATION		WEIGHT	POLAR I	TRANSVERSE I	CG TO REF	VOLUME
1	04	1	.8144	.4346	.0500	4.2092	2.8779
2	5	*	-.4767	-.1649	-.0245	.8313	1.6844
3	07	*	-.7842	-.3250	-.0733	3.4930	2.7712
4	07	1	.2577	.0805	.0490	5.2280	2.6845



OGIVE TEST 57MM

WEIGHT(LBS.)= 2.1577

CG(IN.)= 2.3046

POLAR I (LB.IN.SQ.)= 1.8307

TRANS I (LB.IN.SQ.)= 6.9478

STABILITY FACTOR= 2.32

APPENDIX C

"SPIN 73" PROGRAM

SPINNER 73

5705

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
6.456	1.973	.948	1.852	.266	1.007	**********	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
2.244	1.831	6.948	2.158	30.000	30.000	2.244	60.000	.00237

AERODYNAMIC COEFFICIENTS (RATE COEFFICIENTS BASED ON RATE * (D/2V))

MACH	CX	CX2	CNA	CMA	CPN	CYPA	CNPA	CNPA3	CNPA5	CPF(1)	CPF(5)	CNPA(5)	CMQ	CLP
.010	.103	2.694	1.247	2.784	-.380	-1.128	1.794	125.840	-1220.899	3.443	4.450	2.930	-83.301	-.043
.600	.103	2.694	1.247	2.800	-.393	-1.128	1.794	125.840	-1220.899	3.443	4.450	2.930	-83.301	-.043
.800	.106	[illegible].134	1.267	3.184	-.661	-1.128	2.000	114.362	-1166.120	3.626	4.542	3.033	-83.301	-.041
.900	.160	3.594	1.361	3.065	-.400	-1.257	2.574	83.515	-707.652	3.900	4.501	3.330	-84.213	-.034
.950	.214	4.399	1.111	3.406	-1.214	-1.580	3.422	65.581	-618.311	4.018	4.394	4.016	-85.926	-.030
1.000	.377	4.738	1.429	1.968	.475	-1.451	3.358	44.777	-410.274	4.167	4.447	3.765	-88.887	-.028
1.050	.455	4.346	2.477	.586	1.615	-1.321	3.268	26.843	-230.933	4.325	4.511	3.514	-87.400	-.028
1.100	.451	4.988	2.492	.647	1.592	-1.257	3.214	18.952	-152.022	4.409	4.547	3.388	-88.782	-.028
1.200	.433	5.698	2.541	.671	1.588	-1.128	3.013	13.357	-96.068	4.523	4.633	3.137	-89.696	-.027
1.350	.411	5.219	2.614	.633	1.610	-1.128	3.033	11.051	-73.112	4.542	4.633	3.137	-85.423	-.027
1.500	.392	4.720	2.708	.561	1.645	-1.128	3.095	9.913	-61.634	4.596	4.679	3.188	-78.701	-.027
1.750	.363	4.222	2.801	.442	1.694	-1.128	3.157	8.766	-50.156	4.651	4.725	3.240	-79.614	-.026
2.000	.333	3.729	2.888	.285	1.753	-1.128	3.219	7.618	-38.678	4.706	4.770	3.291	-80.527	-.026
2.500	.293	3.234	2.963	.132	1.688	-1.128	3.229	6.470	-27.201	4.715	4.770	3.291	-81.439	-.025
3.000	.258	2.747	2.889	.152	1.799	-1.128	3.224	5.322	-15.723	4.711	4.756	3.276	-81.439	-.023
4.000	.223	2.286	2.789	.231	1.769	-1.128	3.214	5.322	-15.723	4.702	4.747	3.265	-80.527	-.023
5.000	.204	1.824	2.689	.303	1.739	-1.128	3.188	5.322	-15.723	4.679	4.725	3.240	-79.158	-.022

STABILITY ANALYSIS

MACH	GYRO	SBAR	RECIP	SBAR(5)	RECIP(5)	SPIN	W1	W2	L1	L2	L1(5)	L2(5)	DFLT	DISP
.010	1.930	.196	2.834	.297	1.975	12.5	2.79	.50	-.034737	.002506	-.032378	.000147	.1124	.439
.600	1.919	.196	2.834	.297	1.975	751.2	167.45	30.48	-.034795	.002564	-.032429	.000198	.0019	.435
.800	1.687	.215	2.611	.307	1.923	1001.6	216.17	47.73	-.035898	.003657	-.033566	.001325	.0015	.358
.900	1.753	.264	2.181	.331	1.810	1126.8	245.72	51.17	-.034546	.001913	-.032886	.000252	.0013	.395
.950	1.577	.325	1.837	.377	1.635	1189.4	251.49	61.90	-.034946	.001784	-.033531	.000369	.0012	.245
1.000	2.730	.313	1.895	.347	1.744	1252.0	296.24	33.64	-.031902	-.002538	-.031166	-.003274	.0011	.655
1.050	9.167	.334	1.799	.354	1.715	1314.6	336.66	9.72	-.029144	-.005241	-.028769	-.005616	.0009	5.014
1.100	8.386	.324	1.848	.339	1.776	1377.2	351.60	11.27	-.029846	-.005071	-.029578	-.005339	.0009	4.554
1.200	8.007	.306	1.928	.316	1.877	1502.3	383.09	12.77	-.030545	-.004742	-.030354	-.004933	.0008	4.524
1.350	8.493	.325	1.836	.334	1.797	1690.1	431.82	13.52	-.028785	-.004916	-.028627	-.005074	.0007	5.036
1.500	9.581	.361	1.691	.369	1.660	1877.9	481.56	13.27	-.025976	-.005218	-.025835	-.005360	.0007	6.018
1.750	12.146	.365	1.674	.373	1.648	2190.9	565.16	12.14	-.026111	-.005475	-.025987	-.005599	.0006	8.127
2.000	18.859	.370	1.658	.377	1.636	2503.9	650.90	8.96	-.026209	-.005766	-.026102	-.005873	.0005	13.436
2.500	40.789	.370	1.659	.375	1.640	3129.9	819.62	5.09	-.026392	-.005966	-.026302	-.006056	.0004	30.815
3.000	35.274	.368	1.664	.373	1.648	3755.9	982.58	7.06	-.026420	-.005901	-.026345	-.005977	.0003	26.208
4.000	23.288	.370	1.659	.374	1.643	5007.8	1305.21	14.32	-.026163	-.005763	-.026087	-.005839	.0002	16.748
5.000	17.726	.371	1.653	.376	1.637	6259.8	1625.81	23.60	-.025747	-.005611	-.025671	-.005687	.0002	12.259

SPINNER 73

5705

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
6.456	1.973	.948	1.852	.251	1.007	50.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
2.244	1.831	6.948	2.158	30.000	30.000	2.244	60.000	.00237

AERODYNAMIC COEFFICIENTS (RATE COEFFICIENTS BASED ON RATE * (D/2V))

MACH	CX	CX2	CNA	CMA	CPN	CYPA	CNPA	CNPA3	CNPA5	CPF[1]	CPF(5)	CNPA[5]	CMQ	CLP
.010	.102	2.724	1.240	2.789	-.397	-1.128	1.794	125.840	-1220.899	3.443	4.450	2.930	-83.301	-.043
.600	.102	2.724	1.240	2.805	-.410	-1.128	1.794	125.840	-1220.899	3.443	4.450	2.930	-83.301	-.043
.800	.105	3.172	1.260	3.189	-.679	-1.128	2.000	114.362	-1116.120	3.626	4.542	3.033	-83.301	-.041
.900	.157	3.641	1.354	3.102	-.439	-1.257	2.574	83.515	-797.652	3.900	4.501	3.330	-84.213	-.034
.950	.212	4.454	1.103	3.642	-1.450	-1.580	3.422	65.581	-618.311	4.018	4.394	4.016	-85.926	-.030
1.000	.367	4.801	1.421	2.267	.256	-1.451	3.358	44.777	-410.274	4.167	4.447	3.765	-88.887	-.028
1.050	.436	4.972	1.913	-.136	1.923	-1.321	3.268	26.843	-230.933	4.325	4.511	3.514	-87.400	-.028
1.100	.433	5.072	2.479	.770	1.542	-1.257	3.214	18.952	-152.022	4.409	4.547	3.388	-88.782	-.028
1.200	.418	6.149	2.167	.293	1.717	-1.128	3.013	13.357	-96.068	4.523	4.633	3.137	-89.696	-.027
1.350	.397	5.595	2.316	.390	1.683	-1.128	3.033	11.061	-73.112	4.542	4.633	3.137	-85.423	-.027
1.500	.378	4.803	2.703	.652	1.611	-1.128	3.095	9.913	-61.634	4.596	4.679	3.188	-78.701	-.027
1.750	.350	4.383	2.797	.513	1.669	-1.128	3.157	8.766	-50.156	4.651	4.725	3.240	-79.614	-.026
2.000	.322	3.808	2.888	.341	1.734	-1.128	3.219	7.618	-38.678	4.706	4.770	3.291	-80.527	-.026
2.500	.283	3.292	2.968	.155	1.800	-1.128	3.229	6.470	-27.201	4.715	4.770	3.291	-81.439	-.025
3.000	.251	2.792	2.899	.140	1.804	-1.128	3.224	5.322	-15.723	4.711	4.756	3.276	-81.439	-.023
4.000	.216	2.322	2.799	.220	1.774	-1.128	3.214	5.322	-15.723	4.702	4.747	3.265	-80.527	-.023
5.000	.197	1.853	2.699	.293	1.744	-1.128	3.188	5.322	-15.723	4.679	4.725	3.240	-79.158	-.022

STABILITY ANALYSIS

MACH	GYRO	SBAR	RECIP	SBAR[5]	RECIP[5]	SPIN	W1	W2	L1	L2	L1[S]	L2[S]	DELT	DISP
.010	1.926	.195	2.837	.297	1.975	12.5	2.79	.51	-.034756	.002528	-.032395	.000167	.1124	.435
.600	1.915	.195	2.837	.297	1.975	751.2	167.38	30.55	-.034814	.002586	-.032446	.000218	.0019	.432
.800	1.685	.214	2.613	.307	1.924	1001.6	216.08	47.83	-.035921	.003684	-.033587	.001349	.0015	.356
.900	1.732	.264	2.182	.331	1.810	1126.8	244.95	51.94	-.034694	.002064	-.033020	.000390	.0013	.386
.950	1.475	.325	1.837	.377	1.635	1189.4	245.62	67.77	-.036161	.003003	-.034653	.001495	.0013	.214
1.000	2.370	.313	1.895	.347	1.743	1252.0	290.35	39.54	-.032593	-.001843	-.031822	-.002614	.0011	.544
1.050	-39.410	GYROSCOPIC INSTABILITY												
1.100	6.981	.324	1.839	.339	1.776	1377.2	349.37	13.50	-.030010	-.004900	-.029739	-.005171	.0009	3.787
1.200	18.350	.298	1.973	.308	1.919	1502.3	390.39	5.47	-.030058	-.005048	-.029875	-.005231	.0008	8.944
1.350	13.759	.318	1.866	.327	1.827	1690.1	437.10	8.24	-.028494	-.005062	-.028340	-.005216	.0007	7.287
1.500	8.239	.361	1.690	.370	1.660	1877.9	479.32	15.50	-.026076	-.005115	-.025933	-.005258	.0007	5.144
1.750	10.471	.366	1.673	.373	1.647	2190.9	563.16	14.13	-.026186	-.005398	-.026061	-.005524	.0006	6.983
2.000	15.746	.370	1.657	.377	1.635	2503.9	649.12	10.65	-.026266	-.005708	-.026159	-.005816	.0005	11.203
2.500	34.759	.370	1.656	.376	1.639	3129.9	811.73	5.97	-.026415	-.005946	-.026324	-.006036	.0004	26.349
3.000	38.268	.369	1.663	.373	1.647	3755.9	983.14	6.51	-.026408	-.005918	-.026333	-.005993	.0003	28.650
4.000	24.475	.370	1.657	.375	1.642	5007.8	1305.91	13.62	-.026152	-.005779	-.026076	-.005855	.0002	17.739
5.000	18.360	.372	1.652	.377	1.635	6259.8	1626.64	22.77	-.025737	-.005626	-.025660	-.005703	.0002	12.797

DISTRIBUTION LIST

Commander
US Army ARRADCOM
ATTN: DRDAR-LCF
DRDAR-LCF-T (3)
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